

ASTRONOMY

November 1985

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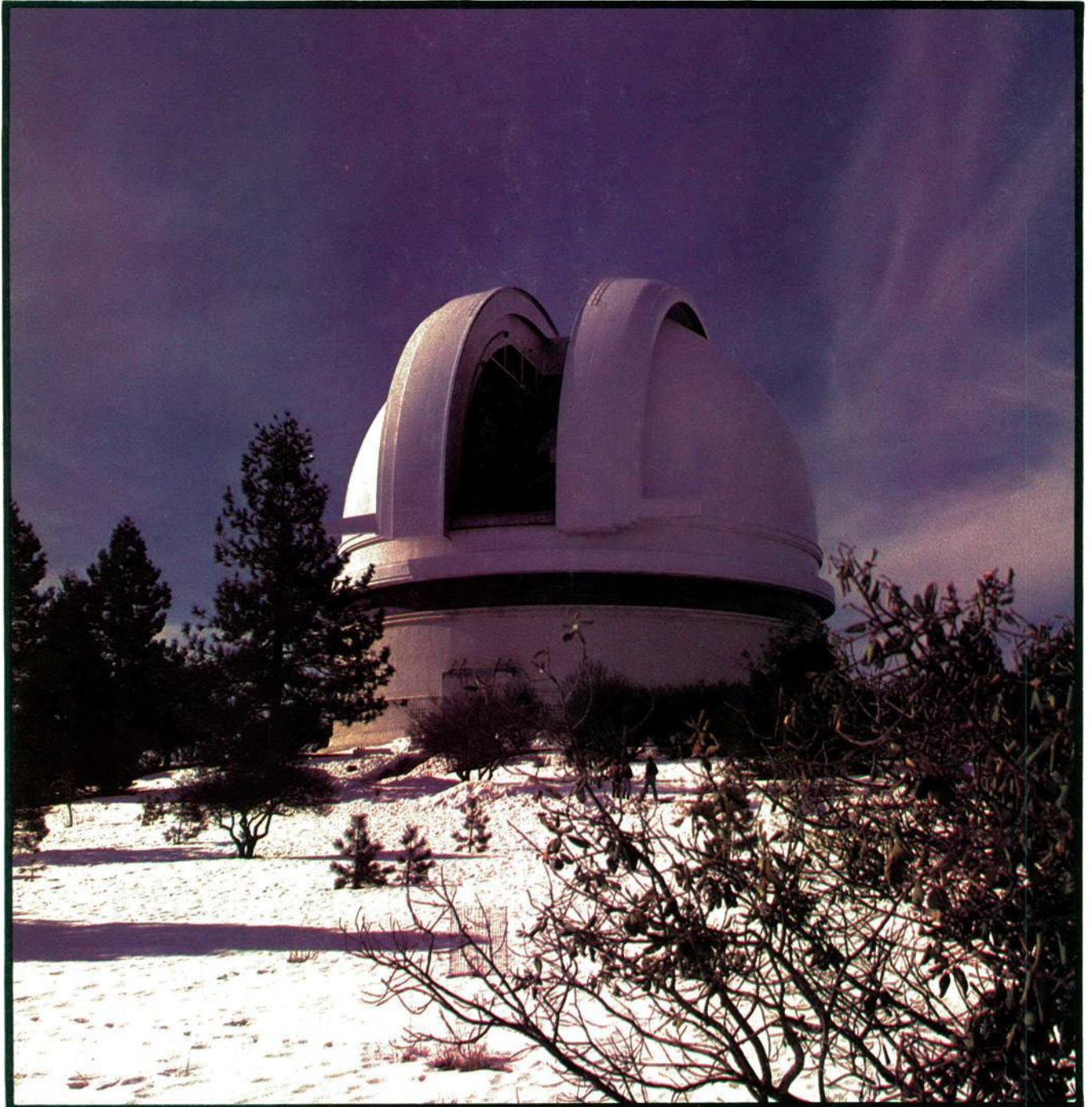
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The Politics of Light Pollution

Gems of the Northern Skies

Your First Shot at Halley's Comet

ICD# 08070



“Bright” Future for Palomar?





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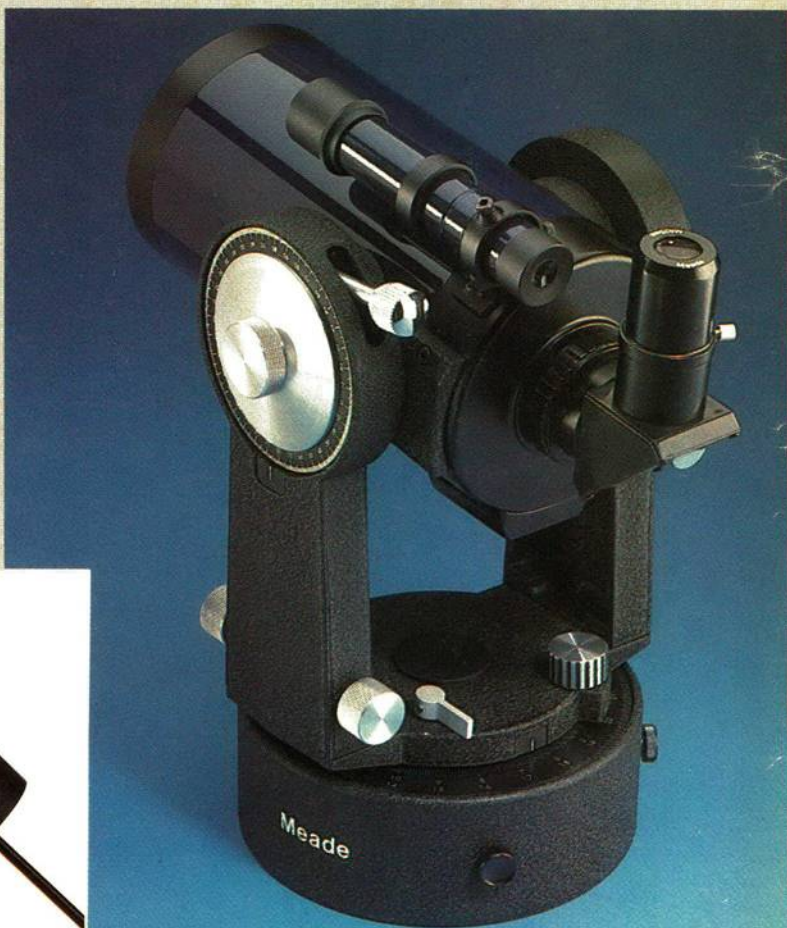
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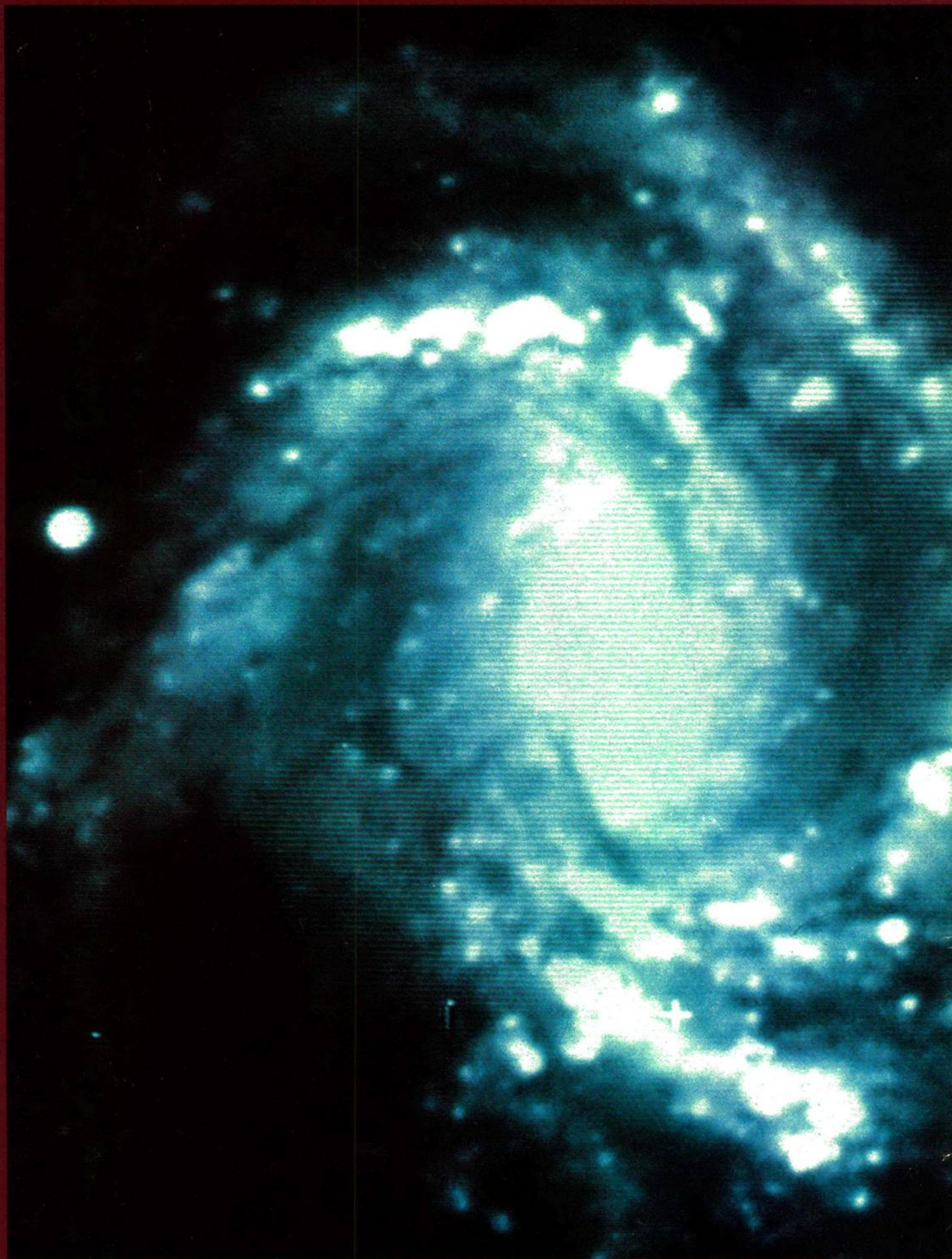
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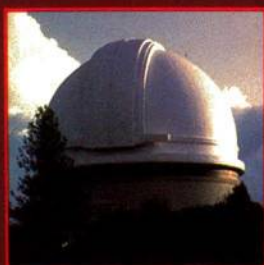
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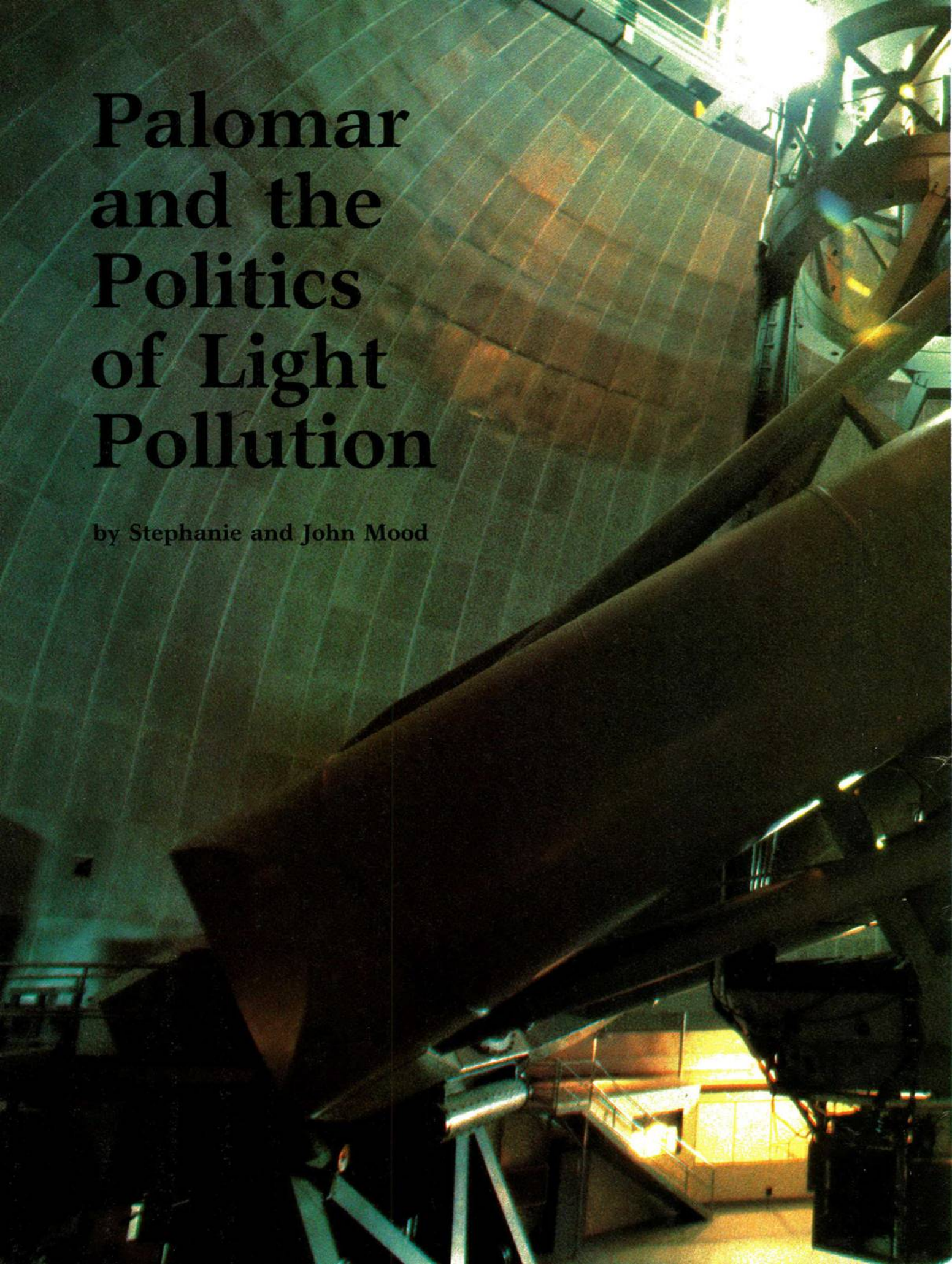
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Palomar and the Politics of Light Pollution

by Stephanie and John Mood







You are about to become one of the very very fortunate of the very few thousand who have ever looked through the 200-inch . . . " It was Saturday, 15 September 1984, close to midnight; perhaps 25 of us stood, hardly believing our ears, as Bob Thicksten, Superintendent and Chief Engineer at Palomar Observatory, spoke these words. With that, he turned and led us back up the same metal stairs we had climbed earlier in the day. Suddenly our tour had turned into a once-in-a-lifetime event and nobody was wasting any time. Inside the dome, the telescope waited majestically.

None of us were professional astronomers; none of us had had to prepare detailed proposals or outlines of work to be done, submitted them a year or two in advance, and taken our chances in the stiff competition for telescope time. We were members of the San Diego Astronomy Association who had been invited by Palomar to come up to the mountain for dinner and a tour of the telescopes — as a "thank you" for our cooperation and help in the battle over streetlighting and light pollution in San Diego.

Unfortunately, the primary source of electricity on the mountain was off due to a lightning strike earlier that evening, so our group was told we wouldn't be able to spend the night at the 60-inch telescope as promised because it had no back-up generator. After the dinner and a look at the sleek 48-inch Schmidt telescope (which was used for the famous Palomar Sky Survey), more than half the group left, leaving a few of us to wait hopefully in the parking lot for the electricity to be restored.

But after less than an hour, during which time we noticed that Algol was in eclipse, Thicksten came driving through the dark in his truck; the back-up generator for the main observatory was supplying such "dirty" electricity to the 200-inch that its state-of-the-art computers and machinery wouldn't run correctly. Since none of the professionals could work under these conditions, the 200-inch was available — for us. Would we care to come on over? We felt like Pizarro being asked if he'd care to look at the fabled Incan treasures.

Our nation came very close to losing Palomar Observatory. We may still lose it. But for now, the bright-light salesmen, the electric companies, and the Public Utilities Commission are going to have to rethink their positions on such policies as advocating as much night lighting as possible. For their part, astronomers are going to have to become what they never wanted to be: politically astute and active. The old practices of presenting arguments in a reasoned way and then expecting agreement from peers will no longer work. Palomar's fight to save the observatory represents a major step in the struggle to stop wasteful lighting, and a major change in scientists' awareness of political processes.

Like many cities over the last 15 years, San Diego decided in the late 70s to change its city streetlights from the old expensive mercury vapor (MV) lamps to a more energy-efficient kind of lighting. The city's electric bill was getting enormous, especially since the mammoth energy crises of '73 and '78, and with no end in sight. What kind of lamps to get was the question. After testing two kinds of yellow sodium lamps, San Diego's City Manager recommended to the Public Safety and Services Committee (PS&S) that the city adopt low-pressure sodium lamps (LPS) as its standard for streetlighting. That report, dated 19 June 1981, was written by Dave Wood, the

Deputy Director of the Electrical Division.

The issue began to heat up almost immediately. Neither the electric company nor the manufacturers nor some of the powerful businessmen liked Wood's recommendation. These people preferred that the city adopt high-pressure sodium lamps (HPS), and advertised heavily — sometimes misleadingly — to get them. Wood maintained that the city could save a lot more money with LPS than with HPS, especially since energy supplies will steadily diminish and energy costs will correspondingly rise. Others claimed that HPS was cheaper and more aesthetic besides. Thus it was that on 18 August 1982, the City Manager's office issued a new report, this time recommending to the PS&S that the city adopt HPS lamps for streetlighting.

But aside from economics and aesthetics, astronomy would play a critical role in this decision — though no one guessed it at the time. Indeed, the second report states: "While we do not diminish the importance of 'dark skies' for the observatory's important work, we do not feel that the overall lighting standards for the City of San Diego should be established in order to achieve *this one specific purpose* (emphasis added)." So much for the future of San Diego County's most famous and important institution, and what is still the finest telescope in the world!

Palomar's problem was clear-cut: HPS lamps emit a broad spectrum of wavelengths, while LPS lamps emit light in a narrow band of wavelengths. Light escaping upward from either kind of lamp brightens the night sky, making deep-sky observations increasingly limited and reducing the efficiency of the great telescope. (Already light pollution had reduced the 200-inch telescope to operating with the effectiveness of a 140-inch instrument.) But the single narrow band of wavelengths from LPS lamps, unlike the broad smear from HPS lamps, can be easily filtered out by astronomers who can then continue to observe at other wavelengths.

Does Palomar face a "bright" future?

Dr. Robert Brucato, assistant director of Palomar Observatory, likens the orange-yellow LPS lights to an old picket fence with only one slat left. The astronomers can easily peer around the slat. The pinkish-yellow HPS lights constitute a brick wall, impenetrable, in Brucato's metaphor. Even the greenish-white MV lights, while less energy-efficient, are better astronomically than HPS, having only four thin slats in the picket fence.

The first PS&S meeting to consider the City Manager's proposal for HPS was finally held, after several frustrating delays, on 29 October 1982. Much of the San Diego astronomical community, having been alerted, showed up ready to present the case for LPS. Besides Dr. Brucato from Palomar, Dr. Gerry Neugebauer, director of Palomar Observatory (and head of IRAS, the InfraRed Astronomical Satellite project, then in its most critical phase in orbit),

Dr. Burt Nelson, director of Mt. Laguna Observatory and Professor of Astronomy at San Diego State University (which operates Mt. Laguna), and members of the San Diego Astronomy Association (SDAA) were in attendance.

It was a weird meeting, with the "heavies" from Palomar, in a soft-spoken rational manner, presenting a self-defeating compromise plan of concentric zones of LPS and HPS lamps. It seemed as though they had already acknowledged the inevitable loss of the observatory's world-famous telescopes. Many of us sat there — stunned — at the political naivete of these world-famous scientists. As Mike Anderson, president of SDAA and a professional electrician, recalled: "I was astounded at Palomar's lack of reality. Dr. Neugebauer and Dr. Brucato were not forceful at all. I thought, 'Boy, they should have sent somebody down here with some weight.'"

With politicians, one asks for more than five times what one is willing to settle for, meaning 10 times more than what one really wants. Palomar had not researched or understood how junior high-schoolish city councils can be. But even more amazing: The PS&S turned around and voted for LPS lighting. They knocked down both the HPS recommendation of the City Manager's second report and defeatist compromise proposed by the Palomar astronomers! We all walked out of the meeting looking like proverbial cats who've just swallowed gift canaries, trying to hide our smirks.

But that was just the first skirmish. The full San Diego City Council now had to act on the PS&S Committee's recommendation. The meeting was held a month later, on 23 November 1982, after a long wait and postponement the day before. At that meeting, the City Council, in spite of a spirited objection from one councilman, voted 7 to 1 for LPS.

In our jubilation, even the more politically astute among us were unaware of the strange twists that had yet to unfold in the months to come. For now the opposition

meeting took up the question again on 21 March 1983 (citing insufficient information on the first vote), even more prestigious astronomers were brought in — most notably Margaret Burbidge, past president of the American Association for the Advancement of Science and the American Astronomical Society. The vice-president of Norelco, a maker of LPS lamps, was brought in to make his case, as was a councilwoman from La Jolla, California, which had recently voted for HPS. She testified that the so-called experts speaking for HPS had lied to the La Jolla council and that she had since gathered all the facts and was now in favor of LPS.

As usual, members of the SDAA also got up and ranted away for LPS, while council members fiddled with papers or whispered to each other. To counter this, a councilman had brought in a bunch of old folks from his district to lobby for HPS. These people all swore they looked like cadavers under LPS. But they had trouble remembering their lines: Mike Anderson remembers hearing one of them ask his wife, "Are we for LPS or HPS?"

The vote was razor-close: 4 to 3 for LPS. Our happiness was muted by the dry relief in our throats. Illustrating the difference in political sophistication between electricians and astronomers, Brucato now ruefully admits, "I found out that you can influence the outcome of a vote by filling up a chamber with people. I would have thought that a professional politician would know that that is not a representative sample."

During our tour of the 200-inch telescope, we had been taken below deck to see the construction and workings of this magnificent instrument. We had also ridden the dome around, some of us completely fooled by perspective as to what was actually rotating. Now the dome was moving again, but it was dark outside. The great observing slit was opening above us; the dim red lights of instruments and dials glowed here and there in the cool darkness.

A few of us even lay down on the floor to watch this incredible mechanical show. The massive 530-ton telescope, delicately balanced in its great yoke, towered a full 11 stories over us. As the slit slowly revealed the sparkling heavens, it was as though we rode aboard a great starship, spanning the past and future. Edwin Hubble's shade rode above us in the prime focus cage atop the telescope, searching the heavens for galaxies. Black holes and quasars beckoned, inviting discovery.

But the line was already forming at the f/30 coude focus of the giant eye. We were going to get to look at the fine globular cluster M-15 in Pegasus. Unexpectedly, there was a problem — the astronomers couldn't find it! They slewed the huge 29,000-pound mirror this way and that, one bunch of astronomers in the computer room shouting out coordinates and Bob Thicksten at the scope repeating "I can't see a thing."

What had happened, of course, was that with the clean electricity unavailable, the computers wouldn't work — which is why we were getting this opportunity in the first place. But without the computers to tell the telescope where to go, the astronomers were "in the dark," so to speak, notebooks clutched in their hands, squinting at the sky and scratching their heads, "Where the hell is that little bugga, anyway? Well, I don't know; it should be right about there."

*Put the light where
you want it. Don't
shine it in your
neighbor's face.*

— the utility companies (who obviously hoped to sell more electricity with HPS because it uses more) and the light manufacturers (who did not hold a patent for LPS) — was aroused. They began to play on the fears of certain segments of the American population. Newspaper and TV editorials appeared. Though studies have shown that most people don't care which type of streetlight is used, the media blatantly leaned toward HPS.

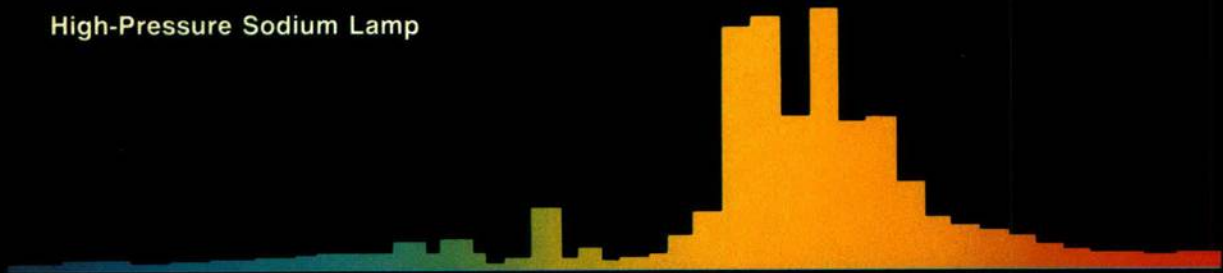
By now, the people at Palomar began to sense trouble. But they also started listening to more politically-sophisticated thinkers, among them Burt Nelson, who had fought waste lighting battles in the early 70s to save the Mt. Laguna Observatory. When another City Council

Street-Lighting Spectra

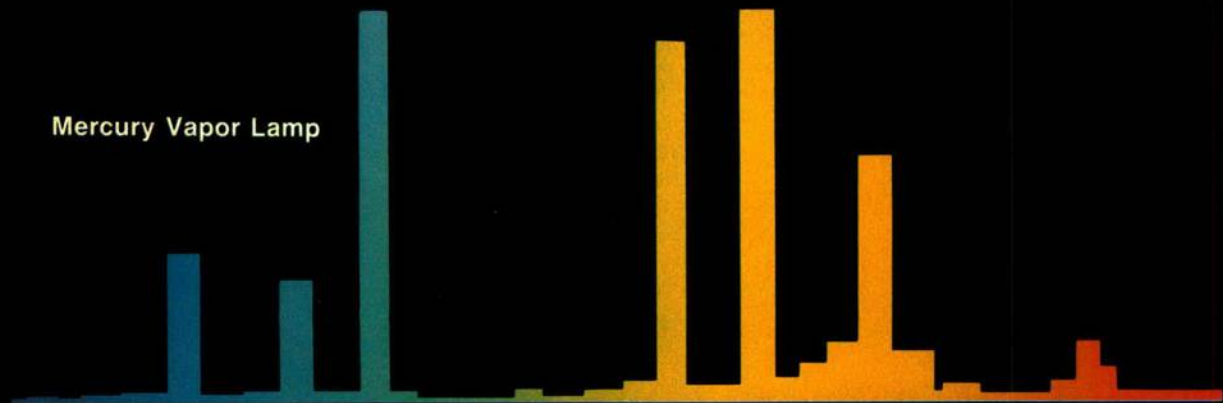
Low-Pressure Sodium Lamp



High-Pressure Sodium Lamp



Mercury Vapor Lamp



The next chapter in the City Council fight occurred while we were absent — far away in Java for the total eclipse of the Sun. It seems that yet another full meeting was called on the question of streetlighting. Through one of those legal technicalities that lawyers thrive on, the council voted once again on 21 June 1983, and this time disaster struck. By a 5 to 4 count, the council voted *for* HPS. Within an absurdly short time, actual conversion of city streetlights had begun in earnest.

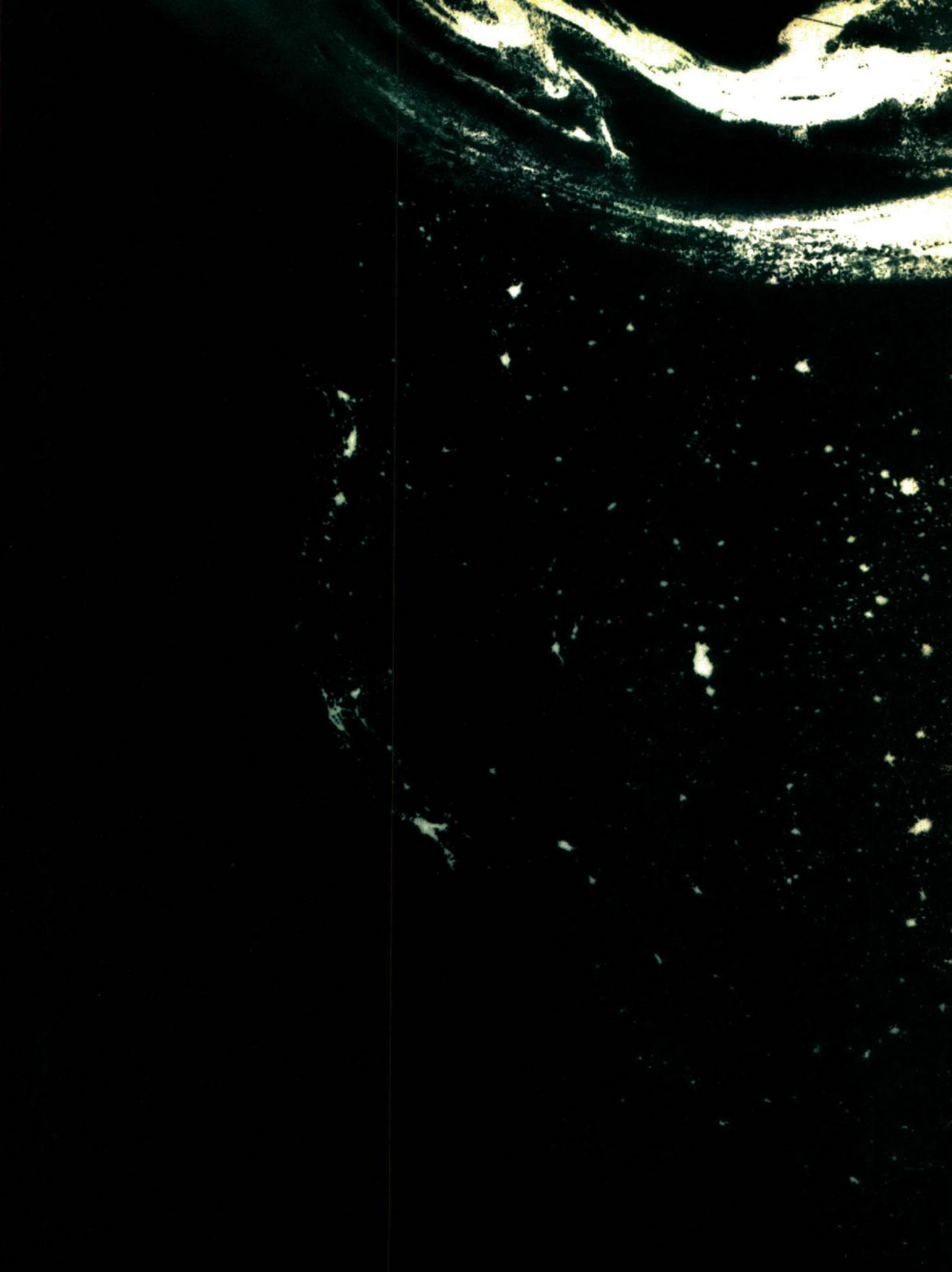
Waste lighting is probably one of the oddest forms of pollution we humans face. Unlike air and water pollution, which often cost millions of dollars to clean up, the solution to light pollution is simple and saves money: just turn off nighttime lights. The only technology needed is the flip of a switch. And if turning off lights is a problem, then use lamps that don't interfere with the dark skies that are everyone's right to enjoy.

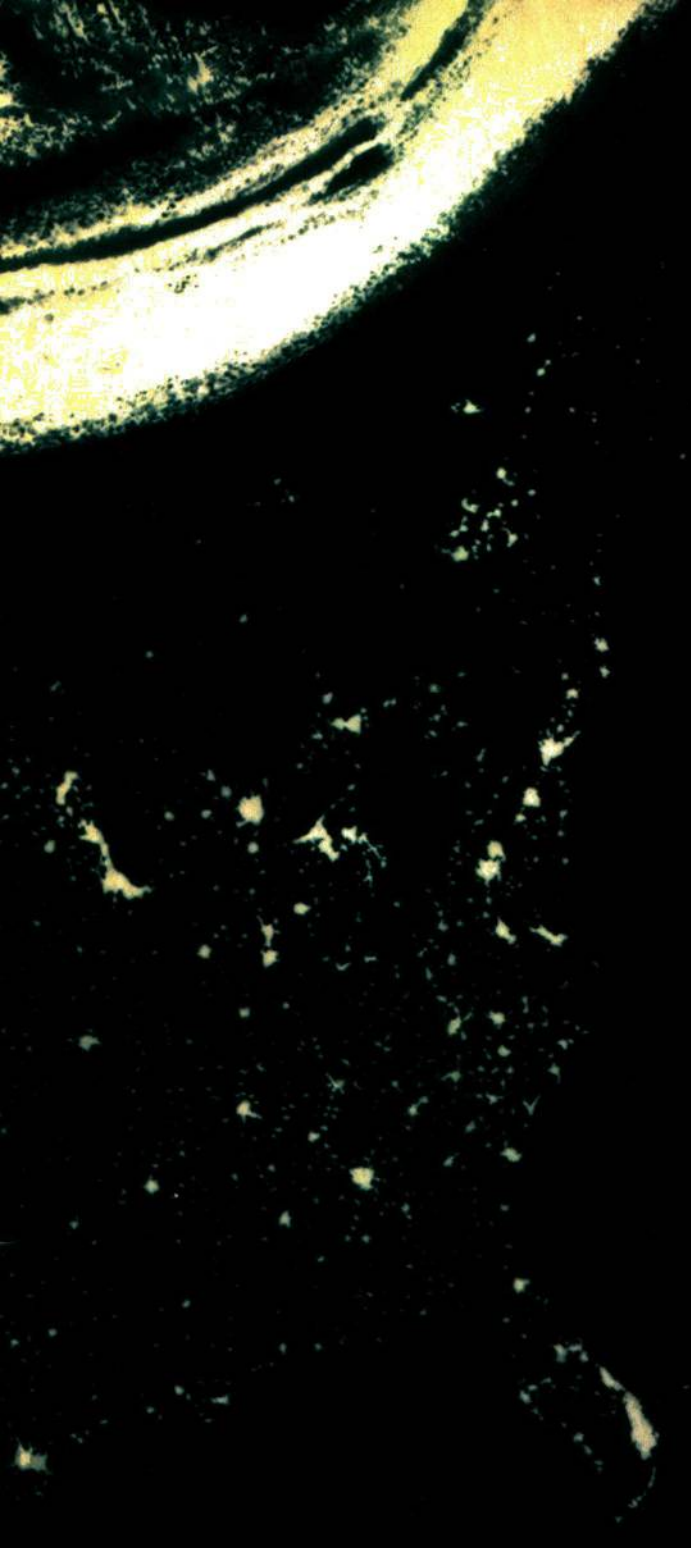
Such lights are readily available and are the cheapest

to run of all currently marketed: they are LPS. The facts on that score are irrefutable, despite a great deal of lighting industry misinformation to the contrary. LPS is the cheapest and most energy-efficient lighting known, no matter what standards are used. No wonder many cities in the U.S., even cities without observatories, have adopted LPS exclusively over the past 10 years.

Unnecessary lights use phenomenal amounts of energy, so much, in fact, that outdoor lighting may soon be the primary cause of society's heavier reliance upon nuclear power. Likewise, turning the night into daylight has undesirable biological effects. Birds, hypnotized like moths, crash into lights and kill themselves by the thousands. Night habitats are destroyed, confusing and causing biological changes in both plants and animals. And when we examine the reasons for our society's love of glaring night lighting, we find little but myth and fear.

Three main purposes underlie our lighting habits: to





The Glare of Night Lights

by Hank Brandli

One of the most recent night mosaics of North America shows spectacular energy waste and light pollution — plus a magnificent display of the aurora borealis. This image was made from data gathered during orbital passes on three moonless cloud-free nights. It was produced by the United States Air Force's Defense Meteorological Satellite Program (DMSP).

The DMSP operation consists of two satellites traveling 900 kilometers high in Sun-synchronous polar orbits. Each carries scanning radiometer sensors capable of viewing the entire Earth in the visible, near-infrared, and infrared parts of the spectrum, both day and night. Two different resolution modes can be used: smooth (1.5 kilometers) for computer processing and storage, and fine (600 meters) for direct real-time use.

The satellites record images on tape at the same local time everywhere on Earth at approximately 8 a.m. and 8 p.m. daily. The polar regions are imaged every 101 minutes, the time it takes for the satellites to make one orbit. Each orbit they scan a swath of ground 3,000 kilometers wide.

Of all the weather satellites in orbit, only the DMSP has a low light sensor able to capture visible images at night, with or without moonlight. City lights, auroral displays, erupting volcanoes, oil and gas fields, lightning, meteor trails, forest fires, and Japanese fishing fleets are some of the phenomena detected by this nighttime radiometer. Most visual sensors "see" from 500 to 700 nanometers, but the DMSP has a range extending from 400 to 1100 nanometers. This wide spectral sensitivity enables the DMSP satellites to detect auroras extremely well because, in addition to the familiar green light humans see, auroras also emit strong emission lines in the near infrared.

Hank Brandli is a satellite meteorologist living in Melbourne, Florida.

City of San Diego Summary of Estimated Street Light Energy Conservation Savings

	Mercury Vapor and Incandescent Lighting	High-Pressure Sodium Lighting	Low-Pressure Sodium Lighting
Phase I — MV & Incandescents	\$1,335,339	\$ 480,670	\$ 386,893
Phase II — Existing — HPS	912,228	710,029	615,084
Phase III — SDG&E MVs at City-Owned Rates	1,084,506	553,836	487,608
Sub-Total Energy Cost	\$3,332,073	\$1,744,535	\$1,489,585
Estimated City Maintenance Cost for Lamping	207,400	234,000	279,400
Grand Total Energy and Lamping Maintenance Cost	\$3,539,473	\$1,978,535	\$1,768,985
Estimated Lumen Output	264,398,860	244,551,430	292,525,000

LPS lighting is \$200,000 cheaper per year than HPS for 50 million more lumens

aid traffic and pedestrians, to attract buyers with glittering displays of advertising, and to deter crime. But new methods of lighting need not interfere with nighttime activities. For traffic, there are alternatives. Present-day automobile headlights are still quite primitive and could be greatly improved. Despite this, much streetlighting is superfluous for cars; in fact, large numbers of HPS lights on freeways actually constitute a hazard — their glare is so strong that drivers cannot see beyond it. In this regard, LPS lighting is far superior, being so glare-free that it is the chosen lighting for landing decks on U.S. Navy aircraft carriers. As for pedestrians, 15-foot-high lights are surely excessive. Three-foot lights would be more useful and would consume far less energy. Or pedestrians could carry small flashlights.

Secondly, business lighting could point downward instead of sideways or straight up, as the lights on many billboards do. Of course, we could ban searchlights —

and banning outdoor car lots wouldn't be a bad idea, either, if for no other reason than their tacky lighting. In any case, there is no reason for advertising lamps to throw light randomly in all directions all night long — how many people are out shopping after 10:00 p.m., anyway? Shutting off such wasteful lighting would cut the cost of doing business. Ordinances requiring all outdoor lights to point down and be shielded below the bottom of the bulb is another obvious step, as would the greater use of dark surfaces such as grass — wouldn't that be a pleasant change? — or new asphalt.

As for the issue of security, people seem to fancy that lights make them safe, when in fact there is not a shred of evidence to support such a feeling. While it is true that human beings are day creatures, the lighting industry has successfully convinced most of them that night is dangerous and should be avoided. This is nonsense, of course — the dark is lovely. Besides, many crimes are

committed in broad daylight; do people really think there was more crime before the invention of electric lights?

But the power of fear is strong, and many a merchant has made his fortune in supplying panaceas for it. In point of fact, there is good reason to think that more lighting increases crimes against property; it pays to advertise, after all, and how is one to know which homes or businesses have tempting goods to steal? In any case, Brucato's suggestion is to "put the light where you want it," rather than shining it in your neighbor's face.

The only objection to LPS lighting is aesthetic, a most subjective matter. We personally like the warm soft glow of LPS yellow. It's certainly preferable to the prison-light greenish-white of mercury vapor lighting. Indeed, when MV lamps were first introduced, people complained about the "sicky purplish" hue — so much so that manufacturers added phosphorus to give MV a more "natural" light. And what, exactly, is the aesthetic advantage of pinkish-yellow HPS light over yellow LPS? Palomar has conducted polls revealing that the majority of people have no problem with the aesthetics of LPS, especially when told that they are better for astronomy.

LPS lamps have benefited from 40 years of research in Europe. Their uniform illumination and widely-distributed patterns, diffused glows merging smoothly one into another, make them superior for streetlighting. And they emit highly visible light — their color (wavelength 589 nanometers) nears the peak sensitivity (550 nanometers) of the human eye.

The battle here in San Diego reached a crucial phase in the summer of 1983. More and more HPS lights were going up and Palomar faced the Los Angelization of the greatest telescope on the planet. Reality began to sink in — the bozos were in the saddle and they meant business. So Palomar decided to lose its civic virginity. The observatory hired an attorney, one who was an insider in the close political and economic circles of the city, one who knew everybody, who was tough, and who knew how to influence childish and venal politicians. There was even behind-the-doors talk about suing the city on the basis of light trespass laws — should San Diego continue to insist on HPS. Nelson, Brucato, and Anderson all now believe that the attorney was the deciding factor in the final outcome.

But that was only one factor in the stepped-up war for dark skies. A nationwide petition campaign began, with positive effects according to Anderson. Big-name American astronomers wrote articles for a dozen major technical journals, and newspapers on several continents carried stories about the San Diego battle. This culminated in Carl Sagan's sharp-tongued essay in *Discover* (October 1983). Its effectiveness is best measured by the resulting howls in San Diego from politicians and capitalists, TV commentators and newspapers.

This media blitz led to the widespread perception that San Diego was deliberately and knowingly destroying a national treasure — which was the truth. (There is even a story that Sagan sent a copy of his book *Cosmos* to San Diego Mayor Roger Hedgecock, and then called him only to be told the Mayor, who had inexplicably voted for HPS, was "not available" to talk.) By the late fall, local newspaper editorials were urging the city to rethink its position. In interesting contrast to others' opinions, San Diego's Deputy Director Dave Wood thinks the involvement of the national astronomical community was the single most important factor in the eventual victory.

And a victory it finally was. On 6 February 1984, by a 6 to 3 vote, the San Diego City Council voted for LPS as the city's exclusive streetlighting. Once again, both armies turned out in full battle gear: professional and amateur astronomers, some now sporting ulcers like medals, and pro-HPS seniors, once again recycling old information, reinventing the wheel one more time. As one councilman said to pro-HPS council members after the vote, "You remind me of nothing so much as flat-earthers. If Columbus had listened to you, he'd still be sailing around the bay."

That decision has since been ratified by the letting of contracts and a planned phase out of HPS and MV lights currently in use. Almost daily we see new LPS lamps going up on the streets of San Diego. In celebration, Palomar named an asteroid for San Diego and invited our association for a tour.

The attempt by Palomar's computerless astronomers and telescope operators to find globular cluster M-15, lost somewhere in the vast reaches of Pegasus, was eventually successful. No one doubted their skill, but it was funny anyway. The view of M-15 was awesome. *Burnham's Celestial Handbook* describes it as "one of the richer and more compact globulars, remarkable for the intense brilliance of its inner core," but now we were seeing that brilliant core completely resolved into countless individual stars, spectacularly luminous. It seemed to dance and glitter. Each of us had to be pried away from the eyepiece so the next could look.

After we all feasted our eyes on M-15, we were treated to the central portion of the great galaxy M-31 in Andromeda. It, too, presented unique thrills: the usually overexposed nucleus a startlingly bright and tiny glow, with the rest of the nucleus looking almost like a huge dim globular cluster completely filling the eyepiece. There were also several bright foreground stars scattered around which are usually burned out in photographs. The three-dimensional massiveness seemed to move and breathe in the vast dark distance. Even Bob Thicksten was enjoying this event.

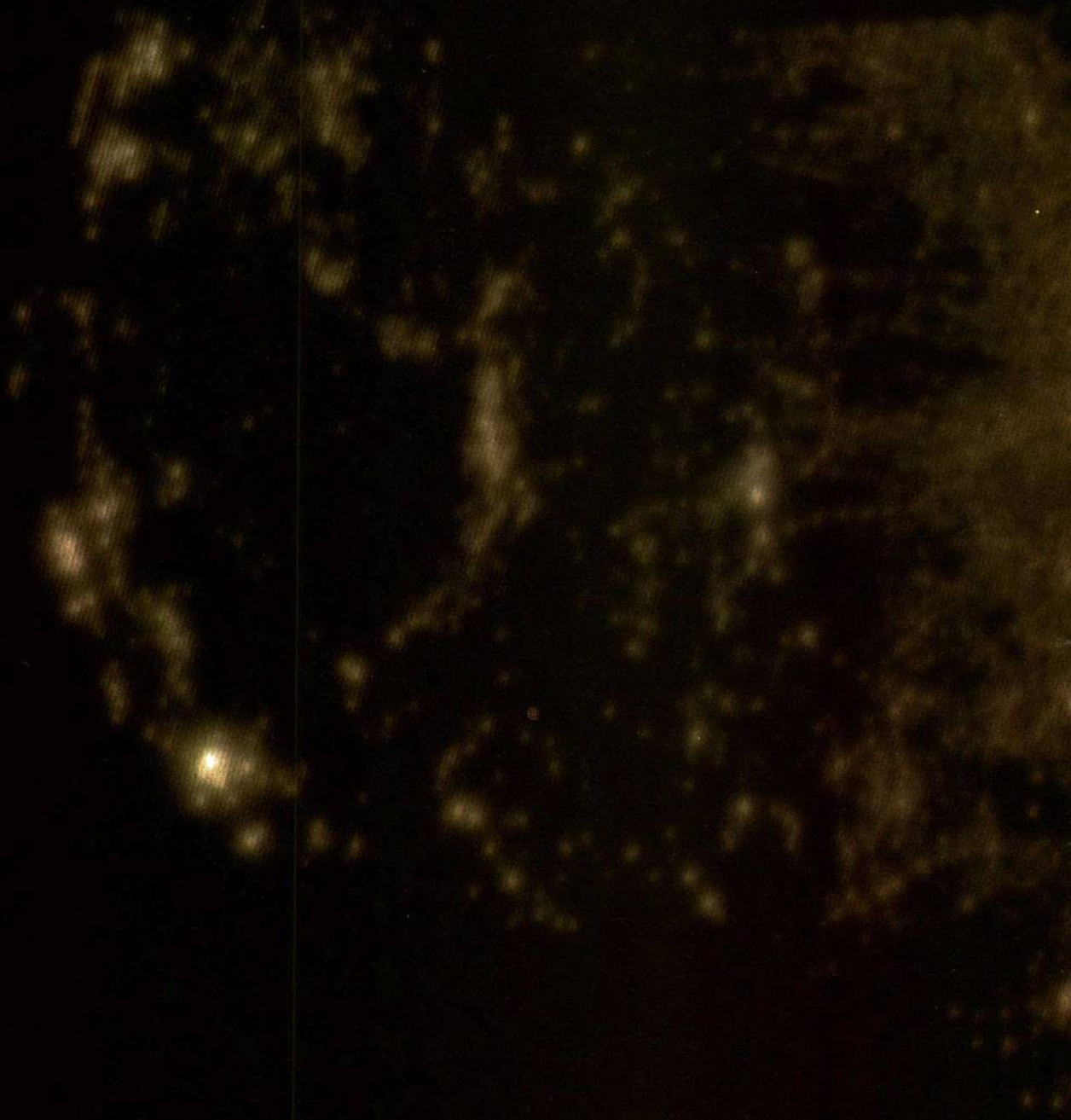
But the inevitable happened: the main-line electricity came back on. Almost instantly half a dozen astronomers appeared from nowhere, hot to resume work on postponed projects. The word came down just as we got to the eyepiece for M-31. The rest of the line behind us was out of luck.

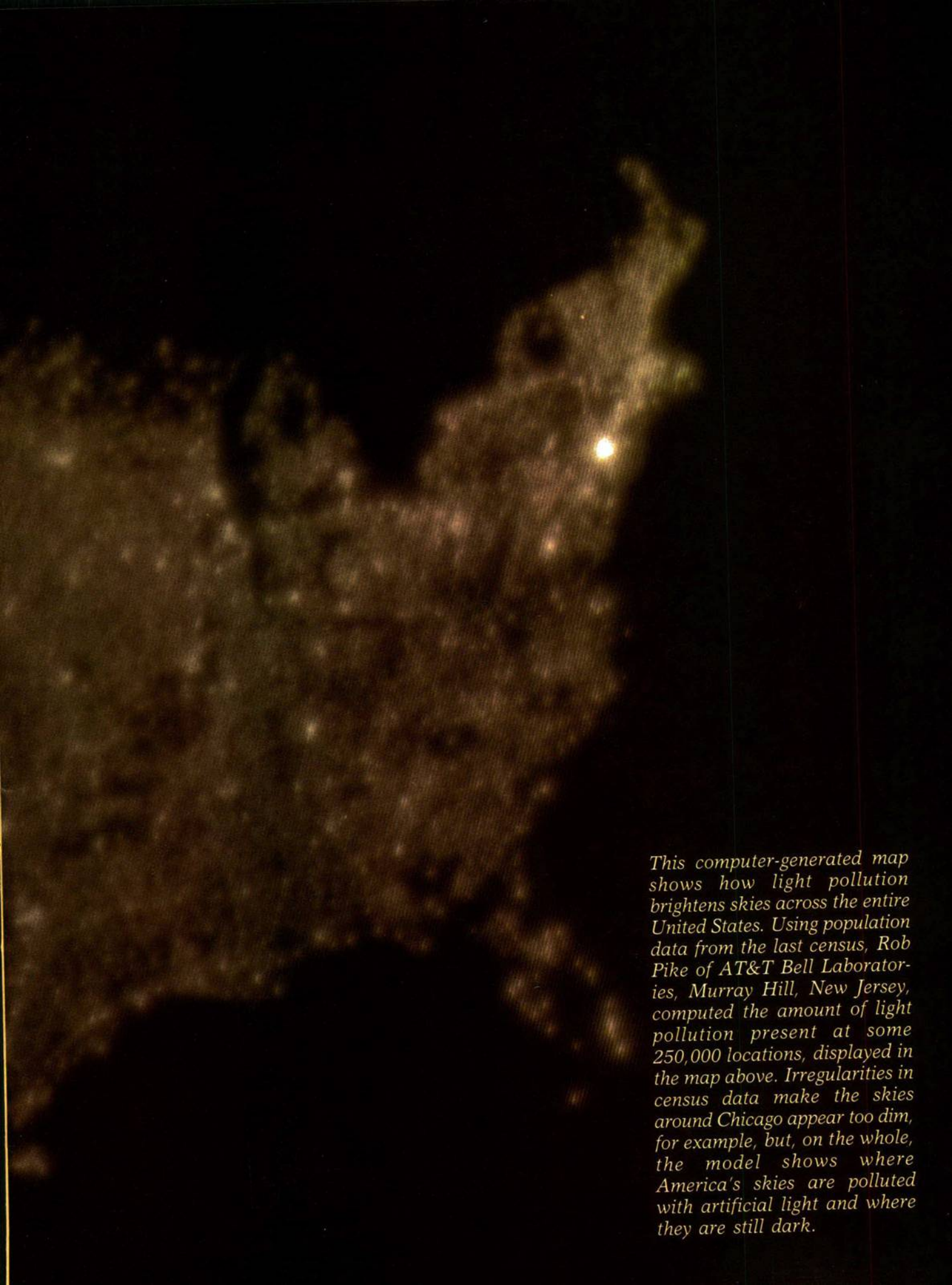
We had won the battle, and a major one it was. Not only had the forces of excess lighting been stopped, but important members of the astronomical community had learned what the real world is like, and what they will have to do in the future to hold the lights at bay.

The war continues. Brucato has, to all intents and purposes, become Palomar's permanent full-time light pollution fighter. He, the attorney, and all their other allied forces recently got the San Diego County Board of Supervisors to enact a statute that requires all commercial lighting in the unincorporated portions of the county to be turned off at 11:00 p.m.

And Palomar has instituted public tours and public use of the 60-inch telescope on selected nights. Brucato's time is now filled with public awareness programs, speeches, and meetings. His approach is simplicity itself:

Light Pollution: A Nationwide Affliction





This computer-generated map shows how light pollution brightens skies across the entire United States. Using population data from the last census, Rob Pike of AT&T Bell Laboratories, Murray Hill, New Jersey, computed the amount of light pollution present at some 250,000 locations, displayed in the map above. Irregularities in census data make the skies around Chicago appear too dim, for example, but, on the whole, the model shows where America's skies are polluted with artificial light and where they are still dark.





Ultra-sensitive CCD detectors have improved the light grasp of the 200-inch telescope and has made the control of light pollution all the more important. CCD images show the core of NGC-4565 (left) and the Horsehead Nebula (above).

"Use a minimum of outdoor lighting, put the light where you want it, and if you're not using a light, turn it off."

But much remains to be done. As Anderson once remarked, "if common courtesy prevailed, we wouldn't have a problem." True enough, but we are not a very polite people. Sensible and civilized lighting policies are needed. We must have shielding on all lamps, restrict unnecessary lighting, permit no lights to shine above the horizontal, and require the lowest wattage lighting possible. And why not have a minimum of two nights every month when we have no lights whatsoever?

Perhaps Palomar gave San Diego too much credit for

the victory; the gift of an asteroid's name should have been saved for a future date when strict regulations have been enacted by every political entity in the country. There are, after all, scores of other light-wasting cities, not to mention thousands of businesses and millions of private citizens.

"Night Is a Right" proclaims an Astronomical Society of the Pacific bumper sticker. This is, in fact, the goal of the Dark Skies for Comet Halley organization led by Fred Schaaf. The imminent return of this most famous of all celestial visitors is fast becoming the single most publicized astronomical event in the space age — an event that has been completely missed by our government. As a result, we must now wait for 2061, the next time the comet returns, before an American spacecraft can explore it.

As a partial compensation, Dark Skies for Comet Halley hopes the citizens of cities and towns across America will show more intelligence than the lawyers in

Mike Anderson

Electrician; President of the San Diego Astronomy Association

I went down to the first meeting [of the San Diego City Council Public Safety & Services Committee]. I was appalled by what I saw. Under the best of conditions, street lighting work is a pain. Under the conditions they were kicking around, zones for different kinds of lights, it would be hideous. They were creating an organizational monster.

I was shocked at Palomar's not being very stiff-willed at all. I was astounded at the lack of reality in their discussion. Dr. [Gerry] Neugebauer [Director, Palomar Observatory] and Dr. [Robert] Brucato [Asst. Director, Palomar Observatory] were not being very forceful at all. I thought to myself, "Boy, they should have sent somebody down here with some weight." They were so obviously cowed by the council.

The Cal Tech astronomers were so used to sitting up on the mountains, being isolated and insulated from the rest of mankind, that they never expected that we'd come after them. Several of the meetings were actually gut-wrenching for these people. You could see their whole little worlds being turned around. They were no longer going to be set aside in their monasteries to make their hand-printed documents, do their rituals in peace and quiet. You could see a large tradition die, and it was kind of sad. But the real world sneaks up on most people.

Palomar got serious after the vote of June '83. Good intentions and positive approaches and presenting the facts had been swamped by very partisan politics. Those astronomers are professionals who when someone places a sheet of facts in front of them, they review them and say, yes, these are fundamentally correct, therefore I agree with your premises. So they presented these same very clear-cut facts to the City Council and got them thrown back at them, like a pie in the face.

Years ago Mt. Wilson and its 100-inch said, don't say anything about [Los Angeles] lights. We don't want our grants to disappear. Don't make any waves. Now look where they sit today. They're dead.

In our system, driving a tractor doesn't put any pressure on Congress. You have to have people come in who talk the language of attorneys and look them eye to eye and say, "You're making a serious mistake." You can hire an attorney for one of two reasons: to protect your ox before it is gored or to sue someone after it is gored. There are light trespass laws. Look at the national treasure [Palomar Observatory] we're destroying for yellow lights with a pink tinge [HPS] or yellow lights with an orange tinge [LPS].

So [Palomar] got an attorney, and a specific one with connections. Now, Brucato is as sharp as a razor, even with the lighting industry people. San Diego was a very large domino.

February 25, 1985

Dr. Burt Nelson

Director, Mt. Laguna Observatory; Professor of Astronomy, San Diego State University

The Mt. Wilson people were originally very isolationist. I received a letter from its director in the early 70's asking me not to mention publicly any problems they were having [with light pollution]. He implied that it would interfere with the observatory's ability to get grants! The first Palomar support came when an engineer, not an astronomer, realized the political seriousness of the threat.

In the mid-70's, the question of the San Diego County Master Plan came up and one element was the preservation of dark skies. We managed to get a pretty good statement recognizing Palomar and Mt. Laguna as sites to be preserved. County officials had never thought of this problem before. At first, when we'd go down to a hearing, they'd literally read their newspapers while we were making our presentation. We'd present our position like we would in the classroom with carefully stated and qualified outlines of the problem. For a long time, the astronomers assumed that, gosh, [Palomar] is such an important institution, how could they possibly let it go down the tubes? I had to remind the San Diego County Board of Supervisors early in the battle that the County Seal, up on the wall right there, had pictures of the history and importance of Palomar. They didn't even realize it was there.

Then, in the early 80's, was the San Diego city battle. At first everybody thought that [light] shielding would be enough, but the Lick Observatory study disproved that. General Electric had already decided to go for HPS [high pressure sodium lights], and everybody went along. I bought it, too. Also, Palomar's original stance didn't estimate correctly just how much light was coming from a distance. They hadn't thought about the cumulative effect of far-off sources.

In the mid-70's we began to learn that there were certain legal aspects, state and federal laws, that protected the environment. What really carried the day was that Palomar was willing to hire attorneys. These guys can walk in at any time. They know the legal ins and outs and the politicians worry about them because they have clout. That led to the key private meeting with [some members of] the San Diego City Council. Dave Wood [Deputy Director, City of San Diego] finally had a chance to give his information about the fact that LPS [low pressure sodium lights] are in fact cheaper. San Diego Gas and Electric had overstepped their boundaries, and Dave Wood laid it on the line. San Diego is not unique in power companies' tactics.

September 19, 1985

Speaking Out on Light Pollution

Dr. Robert Brucato

Assistant Director, Palomar Observatory

You can't argue with a city council — it's like arguing with the referees in football. Your only alternative is to remain calm, facts in hand.

In defense of city councils, [lobbyists] come in every day with a briefing book several inches thick, representing all sorts of interests. Now we're coming in with a highly technical subject — lighting engineering and astronomy. How in the world is a council member supposed to sit there and have one guy say LPS is not efficient and I get up and say it is efficient? Where does a council member go from there?

At the third [San Diego City] council vote [on LPS] in June, 1983, it went against us 5 to 4. At that point, we decided that our problem was getting the information to the council. We needed expert advice, a member of the community who knows how the system operates and can advise us on how to get our info to the council members. Because if you're waiting for your five minutes on the floor, you can't possibly do it. So we hired an attorney to represent us officially. He worked very hard with us and told us the kind of info we needed to provide and we gave it to the City Council and that's finally what did it.

Why, then, has there been such a fight if one has economics on one's side? Utilities in Riverside, California, for example, are offering LPS, which is a major breakthrough. However, they are charging three times as much as for HPS. There's no domestic manufacturer of LPS. But at least they're recognizing a market [for LPS] is here and they're reacting to it. LPS are made by Philips Electric in Europe. And they have said to us, if there's a market, they would consider manufacturing LPS in this country. And at a lighting show I went to last week, a Sylvania representative was showing a wall pack, designed for private use, with a fixture for LPS light.

While there is an aesthetics to LPS, there is also one for astronomy — understand the universe. Observatories must do a better job in public relations. We're going to try to open up the 60-inch at Palomar for two nights a month during the summer. We must try to keep astronomy before the public eye.

December 12, 1984

Dave Wood

Deputy Director, City of San Diego

I came to this position in the city [San Diego] in 1978 with an MBA [Master's in Business Administration], when management encouraged us to look for ways to save the city money. But there's an old maxim around here — the only way you get in trouble is if you try to save money! The Defense Department crucifies people if they try to save money. So I researched LPS and told my superiors that the city could save a lot of money with this kind of lighting.

Initially, they supported me and said, yeah, let's go for it. I'm not sure they realized how much human and emotional energy was going to be used in this issue. They looked at the cost difference and said it's not great enough to fight this. Let the observatories directly take this up with the City Council.

I think our future energy needs are really scary. Part of that problem is that our institutions are not designed for the future we're going into. Incentives are all fouled up. The scientists came in good faith, hoping that the council meant to save money. They didn't realize the entrenched attitude of the utility companies and General Electric. It's a vested interest of manufacturers and utilities, who leave out certain statistics in their arguments. I even went to the California Public Utilities Commission, but they didn't respond either.

I don't think we would have succeeded in getting LPS without the astronomers, economics aside. What won this was the national scientific community and its focus on this city as a progressive or regressive society in terms of science and the future.

September 28, 1984



What does the future hold in store for the 200-inch, or, for that matter, the world's other giant telescopes? Must we expect ever-brighter skies, or can the wonders of the universe be saved for all of us? Photo by Douglas Capps.

Congress — and take this unparalleled opportunity to educate the public about the energy wasted in lighting the night for frightened grown-up infants, to quench the bright lights of the cities below so that the heavens above will again be ours, to capitalize on the interest in Halley's Comet so that we can see it without driving a hundred miles to find the night.

We simply will not have an opportunity like Halley's Comet again. Halley's Comet represents a "carrot" to tempt our nation toward sensible lighting practices, as do Palomar's newly-adopted public relations tours and telescope "open night" programs, or our practice of showing neighbors where Saturn and the Moon are. Can

we really afford to keep wasting energy and lighting our atmosphere in vain attempts to quell our fear of the dark? Do we really want to blot out the nighttime glories of our universe so light bulb manufacturers and electric company shareholders can make a profit?

Given the current fascination with anything having to do with space, why can't we translate the public's interest in Halley's Comet into a cheap and sane lighting policy? If we don't succeed, we will not only deprive our children of their right to the wonders of the heavens, but will also squander the energy that will become increasingly precious in the decades to come. This is what the San Diego fight was all about.

Stephanie and John Mood are free-lance writers actively involved in amateur astronomy. Their most recent contribution to ASTRONOMY, "You Are Going to an Expedition, Not to London," appeared in the December 1984 issue.



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ASTRONOMY Forum



Stages

Throughout the night, arc lights kept the rockets glowing a brilliant white, visible to the hundreds of thousands of people gathered on the beaches miles away. People continued gathering through the night and morning until there were a million humans crowded along the highways and the shores. They gazed through the darkness at the rocket, and when the arc lights were replaced by the Sun, they gazed through the haze of a warm summer day at the towers and buildings of the entire launch complex where the rocket stood thirty-six stories tall. To some people, the rocket seemed like a lone skyscraper, yet within this skyscraper was an enormous amount of power, power enough to lift its six-and-a-half million pounds into the sky. All of this energy would be spent, and all of this six-and-a-half million pounds would be lifted so that three hundred-and-thirty pounds of it — two humans — might arrive at a far destination, the surface of the Moon. At each stage of the flight, the rocket would pour out

the energy needed to carry the rest onward until the mission reached a final stage where the outflow of energy would come from human hands digging into the Moon.

For hours, the million people waited, and the men inside the rocket waited, and the rocket waited. Suddenly, the waiting was over. The five engines at the base of the rocket poured out flame — massive, fierce, and brilliant.

Perhaps there was something before the Big Bang, perhaps matter that gathered until it was so dense that it exploded. Or perhaps there was nothing, only dark space that waited and waited, until suddenly the waiting was over and from the darkness of space there poured out flame, massive, fierce, and brilliant.

The flame pounded against the ground, steam and smoke rolled into the air, and slowly the rocket rose. It rose out of the steam and smoke, climbed above its launch tower, and rose faster and faster, pouring out a flame longer than the rocket itself, dense turbulent flame that shook the air and the ground. The million people felt the rocket's power in their vibrating flesh and bones. They watched the rocket climb through the clouds and disappear into the sky, until all they could see of it was the flame and then not even that. In two-and-a-half minutes, the rocket was fifty miles downrange and over thirty miles high. Then the fuel in the first stage was gone, the flame shut off, and the first stage broke from the rocket and fell toward the Atlantic.

For a moment there was only energy, a ball of unbelievably intense energy swelling outwards. At once some of the energy congealed into particles which swarmed through the energy. The particles collided with one another and ricocheted apart, but often

they fused, becoming hydrogen and then helium. As the fireball spread outwards, its intensity fell and nothing larger than helium was formed. As the fire of the Big Bang faded away, the universe raced onward through space.

Seconds after the first stage fell away, the engines of the second stage ignited. They poured out a flame smaller than the flame of the first stage, which had needed seven-and-a-half million pounds of thrust to get the rocket this far. With the first stage gone, less than a third of the rocket's initial weight remained and a mere million pounds of thrust carried it upward. In six minutes, the rocket was a thousand miles downrange and a hundred miles high. This was as far as the second stage could carry it, and this stage too fell away.

Long after the Big Bang, trillions of smaller fires ignited from the darkness. A small portion of the Big Bang had turned into hydrogen and helium, and now a portion of this matter turned into stars. Over the eons, a small portion of the matter in stars was further transformed. Atoms swarmed about and collided and fused into larger and larger atoms. Finally, the stars exhausted their fuel and shut off; they fell apart, hurling their atoms into space.

After the rocket's second stage fell away, less than one-sixteenth of its initial weight remained. The third stage engine ignited with two hundred thousand pounds of thrust, carrying the rocket into orbit. After a few orbits, the third stage engine ignited again. It burned for six minutes, breaking the rocket from orbit and speeding it toward the Moon.

The matter that was hurled from dying stars wandered through space. Eventually it drifted into thick clouds that contracted and became new stars, but a small portion of it became planets orbiting the stars. Most planets consisted of endlessly swirling gas, ice or sun-scorched rock, volcanoes, craters, grey mountain ranges, and valleys that tore across hundreds of miles of planet surface. Sand swirled from dune to dune, and dust and rock sat motionless for billions of years. Yet some planets went on to become something more.

The command module fired its small thrusters and separated from the third stage. It slowly turned around and linked up with the lunar module within. It fired its thrusters again, pulling the lunar module free. It turned, pointed itself toward the Moon, and fired its main engine. Of the rocket's initial weight, ninety-eight percent had been spent to carry the rest this far.

The vast majority of the universe's initial substance had been spent as fierce energy flying from the Big Bang,

yet this fierceness carried a tiny bit of matter to a sophisticated order: life. The oceans of perhaps billions of planets filled with single-celled creatures. On a portion of these planets, life evolved into larger shapes. On a portion of those planets, life advanced onto land. And on some planets, something within the skulls of life went right on advancing.

The spacecraft neared the Moon, fired its engine to slow itself, and slipped into orbit. The spacecraft circled the Moon, then the two astronauts climbed into the lunar module, brought it to life, and edged it away from the command module. Of the rocket's initial weight, only the lunar module — one half of one percent of it — would reach the Moon. The descent engine fired. The lunar module headed down. It drifted over mountains and valleys, over dead volcanoes and lava flows, over craters and rubble thrown from the craters, over miles of battered stone, over fields of dust, a tiny silver bead steadily descending onto the immense greyness of the Moon.

On the planet Earth, creatures with awareness went on evolving and perceiving the world around them better, until at last there appeared a species that could glimpse the process that gave them birth. Humans gazed billions of years into the past. They saw the stages through which life on Earth had evolved from a planet covered with dust into a planet covered with cells. They saw the stages through which a cloud of gas and dust had turned into the solar system. They saw the stages through which stars evolved and through which hydrogen and helium were turned into the heavier atoms that became planets. And finally humans saw the stages through which matter had emerged from the fire of the Big Bang.

Humans gazed into space and saw what was left from the stages of cosmic evolution: the energy flying through space since the Big Bang, the billions of stars and corpses of stars, the drifting clouds of gas and dust, the planets and the moons. And humans set out to explore that energy and matter.

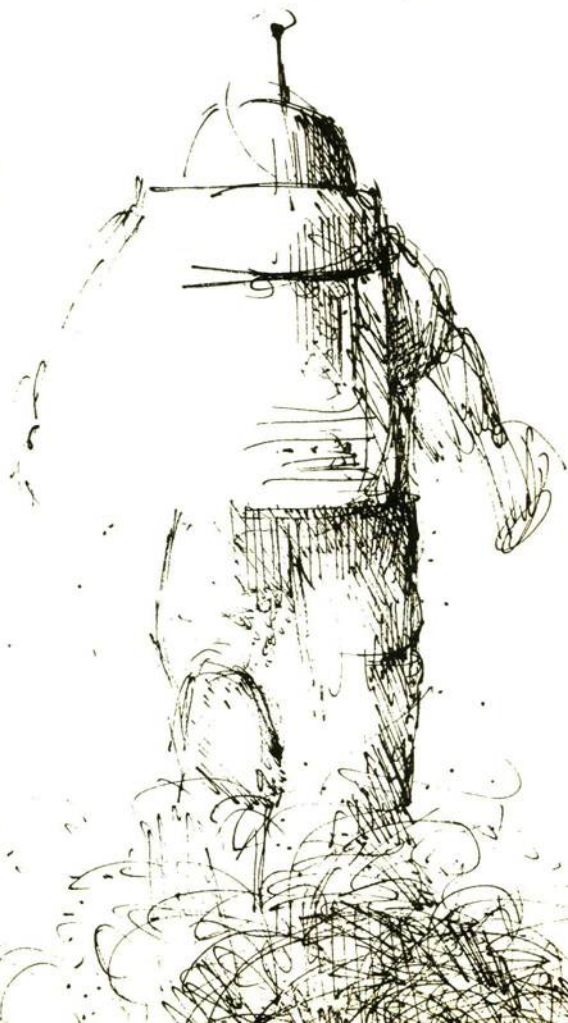
Three hundred feet, two hundred feet, one hundred feet, the lunar module descended. It floated over some rough terrain, heading for a smoother patch. At thirty feet it stirred the dust with its engines. Twenty feet, ten feet, five feet, and then it settled onto the Moon.

Yet the descent still was not complete. After a while, a door opened on the lunar module. A human being emerged, descended a ladder, and stepped onto the surface of the Moon. Soon another human emerged from the module and climbed down

the ladder to the Moon. The humans moved back and forth, two apparitions gleaming white and silver, amid a vast plain of formless grey dust.

An enormous amount of matter and energy had been spent to deliver two humans to this lunar plain. A rocket of six-and-a-half million pounds had been spent stage by stage to deliver the three hundred-and-thirty pounds here. Yet this journey did not begin with the rocket's ignition. The rocket was but the uppermost stage of a million stages of cosmic evolution. This journey began with the ignition of the Big Bang and its massive energy and matter, which formed galaxies, quasars, stars, supernovas, swirling clouds of gas and dust, whirling solar systems, the weather and geology of Earth, and four billion years of organic evolution on Earth — all to deliver a tiny amount of matter to consciousness. This consciousness spent even more matter and energy in creating a rocket that carried it to the Moon, to enable consciousness to unfold and understand the enormous amount of matter and energy spent in its creation. All of cosmic evolution had delivered these two bobbing specks of consciousness onto this plain of dust, and through their studies and samples, the cosmos was looking back at the stages of the journey it had made.

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Wolf Creek Odyssey

For eons the small asteroid had wandered through the lonely depths of space, but now its days were numbered. An encounter with the giant planet Jupiter had thrown it into a collision course with Earth. Without warning the asteroid plunged through the atmosphere in a fiery descent that made the Sun seem puny, before destroying itself in a titanic explosion as it struck Earth. Rocks were thrown in all directions, dust was flung high into the atmosphere, and a huge crater was blasted in the land men would one day call Australia.

In another part of the solar system the Sun was a dim, distant speck, but the ball of ice and rock could feel feeble rays of warmth as it grew

Although the meteors travel in parallel lines, an observer on Earth perceives them as diverging from one central point in the sky, called the radiant. Since the angle at which the meteors strike Earth's atmosphere causes them to be visible for only a short period before dawn, calculations show they are best observed from a latitude of 14° south. This, coupled with southern Western Australia's extremely dubious weather in early May, were the main incentives for going to Wolf Creek in Western Australia's far north. Situated at a latitude 19° south, it was a near-ideal location under almost-guaranteed cloud-free skies.

Originally planned for 1974, the trip had to wait a frustrating 10 years. Finally, in the last year when the Eta Aquarids could be observed without any interference from the Moon, and before Comet Halley reaches perihelion, I was able to go.

After leaving Perth, my first port of call was the mining town Karratha nearly 2,000 kilometers to the north, where a friend had arranged for me to give two lectures on astronomy at the high school. He had also arranged for a student, Christian Sims, to accompany me. Further good news awaited me upon my arrival. Hamersley Iron, Ltd. had generously agreed to provide us with a four-wheel drive vehicle for the expedition, and Woodsie-Burma had provided \$200 toward fuel expenses.

Friday, April 27

Following the usual last-minute panics and holdups (including a frantic rush to fly in some forgotten film), we left Karratha at mid-afternoon, just in time to avoid a drenching thunderstorm — not a good omen for the start of an expedition such as ours. Indeed, we camped at South Hedland and the sky was cloudy for most of the night. We weren't concerned, however, since we were not going to begin observing until the following evening.

Saturday, April 28

The day dawned clear, but quickly became overcast. By the time church services were finished, it was obvious the region was in for more thunderstorms, so it was with considerable concern we continued our journey north. By nightfall, we had left the clouds behind and although there was considerable lightning on the horizon, the sky was dark and clear. The waning Moon hindered our observations of the Eta Aquarids to a small extent, but by tomorrow night we knew that it would also be gone and the real work would begin. In 90 minutes observing, we saw 46 meteors — 10 of which were Eta Aquarids.

Sunday, April 29

As the Sun rose, our day started with what was to become a set pattern: finish observing at daybreak, write up our observations, prepare breakfast, and pack up camp. The planned itinerary for the day was to tour a number of scenic areas before camping near the town of Fitzroy Crossing. Unfortunately, this caused a minor disaster. Some of the tracks were so rough that the esky (ice box) containing the spare film was upset. Since the esky also contained margarine and beetroot, the resultant mess effectively stymied the photographic side of our expedition. But with the Moon no longer causing problems, the number of meteors we observed was considerably higher; in two hours of viewing we recorded 85 (including 31 Eta Aquarids).

Monday, April 30

We had originally intended to reach the meteorite crater this morning, but with so much fascinating country around, we spent most of the day sightseeing. Situated some 150 kilometers north of the crater, Hall's Creek is the nearest civilization. We had hoped to charter a plane in Hall's Creek for a flight over the crater, however, on arrival we were disappointed to find that the only suitable plane was being overhauled. As evening approached, we decided to camp at the ruins of an old gold-mining town a short distance away. In the early hours of the following morning under superbly dark clear skies, we logged an additional four-and-a-half hours of observing, and recorded a combined total of 208 meteors — 60 of which were Eta Aquarids.

Tuesday, May 1

After spending most of the morning fruitlessly panning for gold, we headed for the crater. Proceeding south from Hall's Creek, we quickly left spectacular hilly country behind and began to traverse flat, semi-desert terrain which stretched to the horizon. About two hours later, we sighted the crater — a low, unimpressive range of hills — in the distance. To reach Wolf Creek we had to turn off the main road and (typically) we took the wrong track, which shortly degenerated into a highly overgrown and almost impassable pair of wheel ruts winding through the scrub. We eventually managed to get to the crater despite a considerable amount of jostling and bumping and almost getting bogged.

Upon arrival, we climbed up the crater wall. What a surprise when we reached the top! From the foot of the western wall, the crater appears as a small hill of jumbled, fractured rock, but from the top you can see it for what it is: a huge bowl measuring about one kilometer across. The crater

closer. For thousands of years the comet had been circling the Sun, slowly disintegrating each time it passed by. Debris spread along the comet's orbit and a small planet — Earth — periodically passed through it to produce a spectacular display of celestial fireworks — the Eta Aquarid meteor shower.

Two totally unconnected events. Yet both encouraged me to undertake a three-week, 10,000-kilometer odyssey to observe the Southern Hemisphere's most spectacular meteor shower, the Eta Aquarids, from Wolf Creek Crater, Australia's largest meteor crater.

The Eta Aquarid meteor shower occurs each year in early May, when debris from Halley's Comet encounters the Earth. The debris burns up in the atmosphere and produces what are popularly known as "falling stars."

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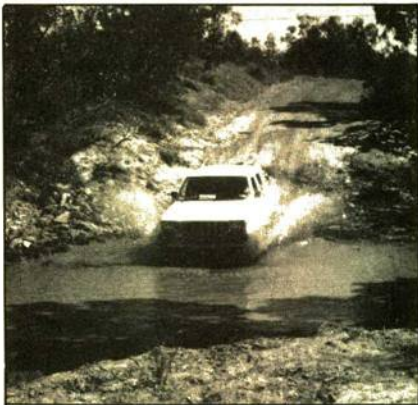
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is almost perfectly circular. Its interior wall plunges much more steeply than the exterior slopes, while the floor lies well below the level of the surrounding plain. Dotted across the floor are a number of trees that make the crater appear deeper than it really is. Altogether the sight was breathtaking; no photograph could ever hope to portray it accurately. Though the sight was magnificent, we could not linger; night was approaching and we had work to do. A detailed examination of the crater would have to wait for another day.

With the predicted maximum for the Eta Aquarid shower only four nights away, good rates were expected and we were not disappointed. We recorded 77 Eta Aquarids out of a total of 219 meteors in five hours observing. One surprising trend was now evident. As maximum approached, the



percentage of bright meteors increased. During 13 years of meteor observing, I had never recorded any such trend for the Eta Aquarids before.

Wednesday, May 2

Most of the day was spent catching up on paperwork and setting up a permanent camp. We erected two small tents for sleeping next to the vehicle and spread a large tarpaulin above them for shade. The shaded area was large enough for a trestle table and chairs, which meant we could stay comparatively cool while writing up the previous night's observations and planning the next night's work. Our equipment load included a number of 20 liter containers of water and fuel, various boxes of food and cooking utensils, sleeping bags, mattresses, spare clothes, radio and tape recorders, plus three telescopes. With such a conglomeration of gear, it was surprising that we had sufficient room for such low-priority items as two observers!

With the telescopes now set up, general observing and photography occupied much of the evenings with only a short period of sleep before starting meteor observing. Because of

this, we got into the habit of sleeping most of the mornings so we would be fresh and alert the following night. The Eta Aquarids' hourly rate continued to climb as the night of maximum approached, but were only marginally higher than in previous years. It was beginning to appear as though the enhanced rates predicted by some astronomers would not eventuate. In five-and-a-half man-hours of observing, 302 meteors — including 124 Eta Aquarids — were recorded.

Thursday, May 3

A number of scrub fires flared up during the day and made a spectacular sight that night from the crater rim. We were extremely fortunate because strong winds kept the smoke away. While setting up our equipment, a brilliant meteor momentarily bathed the landscape in an eerie blue light that burst through the western sky. About as bright as a Half Moon, it seemed like a promising omen for the night's observing. It certainly turned out that way, for in five man-hours of observing, we recorded 470 meteors, including 177 Eta Aquarids. Many were very bright and left persistent trains.

Friday, May 4

Much of the day was spent writing up the previous night's observations and discussing what we were doing with a surprising large number of curious tourists who were visiting the crater. A few times we heard comments which amounted to: "Fancy spending a week camped in the middle of nowhere like this. They must be mad." At least hardly anyone called us astrologers!

No observations were planned for that night as it was the Sabbath.

Saturday, May 5

After worship in the morning, we set off to thoroughly explore the crater. Walking around the rim, it was obvious that the ejecta blanket was more extensive on the southwestern side, indicating that the meteorite was traveling from northeast to southwest. The interior walls also suggested this. The southwestern walls were not as steep as the northeastern ones, which contained a number of small cliffs. On the eastern side of the crater, a sand dune has spilled into the crater. The rocks forming the walls are fascinating. Predominantly quartzite, they have been severely shocked and fragmented. Most pieces are quite small, but on the southwestern side there are a number of large boulders on top.

The floor of the crater is generally flat and filled to an unknown depth with sand; much of it is covered by spinifex and scattered trees. Near the center, the vegetation changes abruptly, becoming denser and greener. This central region contains a number of sink holes and a

considerable amount of gypsum. These holes are filled with water, but to judge by the number of bones scattered about, it isn't particularly drinkable.

The crater acts as a natural amphitheater and a loud bellow from the center results in some rather spectacular echoes. Searching around the southwestern side, we found what may be meteorite fragments. At present, we are waiting to hear about them from the Western Australian Museum.

When we resumed observing, it was just a few hours after the Eta Aquarid's predicted maximum, so we anticipated very high rates. We were not disappointed. In five man-hours of observing, 241 Eta Aquarids were recorded out of a total of 469 meteors. At one stage, the Eta Aquarids occurred at a rate of two per minute.

Sunday, May 6

Much of the day was spent going over the previous night's observations; however, we managed to find some time for a further meteorite searching. In planning the coming night's work, we decided to start observing two hours earlier than usual. This would enable us to closely monitor a region of the sky rich with meteors, without interfering with our work on the Eta Aquarids.

When we started observing, we expected to see only moderate activity until it was time for the Eta Aquarids; however, what we saw was better than anything we could have hoped for. During the first hour we recorded a combined total of 117 meteor and 163 in the second! At one point, we observed nine meteors in only six seconds, and we were stretched to the limit trying to record them all on tape. As we discovered the following day, several were lost in the panic. During this time, we were also treated to the spectacular Eta Aquarids, even though the radiant was still below the horizon. A brilliant orange one traveled over more than half the sky, while another almost as long glowed a deep vivid red.

High meteor rates continued as we switched to the Eta Aquarid's region, with the activity being only marginally less than the previous night. The volume recorded was so high that during the final hour of observing, details of each meteor had to be considerably abbreviated to avoid running out of tape. The final tally from nine-and-a-half man-hours of observation was an incredible 698 meteors — 173 of those Eta Aquarids.

Monday, May 7

We intended to leave the crater on this day, but decided to postpone our departure until Tuesday, so that we could spend another night monitoring the area of sky where we had

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observed large numbers of meteors. It took almost the entire day to write up the night's work. During the day, a number of coaches, packed with inquisitive tourists, arrived at the crater, so we gave a number of impromptu lectures on astronomy. It was rather interesting to see the reactions when we mentioned that we had seen over 600 meteors the previous night. Most people didn't believe us and finally left us alone to continue our work.

That night we continued observing the new region. By midnight, it became apparent that those previously high rates would be repeated. In two hours, we recorded a combined total of 312 meteors! Equally surprising were the Eta Aquarids, which were just as numerous as the night before. In previous years, the rates had dropped markedly this far past maximum. Once again, we were in danger of running out of tape. By the time dawn put an end to the show, we had recorded 200 Eta Aquarids out of a total of 631 meteors.

Tuesday, May 8

At last it was time to start the long drive home. After several hours of packing tents, telescopes, clothes, etc. into the vehicle, I ran up to the crater rim for one final look. Standing there, I again tried to picture what it would have been like when the meteor hit. It must have been a fantastic sight.

Starting up the engine, I felt some regret at having to leave. The past week had been hectic, but enjoyable. I had seen fantastic scenery, a spectacular display of celestial fireworks, and had a rare opportunity to view far northern regions of the sky not visible from home — including my first view of the entire "Big Dipper." But there was still much to do. We had a long way to drive before we could make camp, and we still had most of last night's observations to write up.

At sundown we finally made camp, 50 kilometers east of Fitzroy Crossing, and commenced working on the taped observations, a job that took until nearly midnight.

By now we had been without sleep for nearly 48 hours and the strain was beginning to tell. But after a short rest, we were out chasing the Eta Aquarids once again; yet although the rates were still very high, excessive tiredness forced a halt after only 90 minutes. To

continue would have resulted in data so inaccurate it would have been useless.

Wednesday, May 9

Exhaustion forced us to spend most of the day relaxing. A two-hour drive brought us to picturesque Geigie Gorge, where we spent most of the day swimming and panning for gold. Although it put us behind schedule, it refreshed our spirits after nearly two weeks of busy activity and little sleep. Late in the afternoon, we reluctantly turned our backs on this beautiful spot and began a six-hour drive to our proposed observing site at Willare Bridge, not far from Broome.

Observations that night totaled five-and-one-half man-hours and yielded 412 meteors, including 152 Eta Aquarids. It was surprising that the Eta Aquarids were still displaying rates in excess of 40 per hour. In previous years, the rate had dropped below 20 by this time. The percentage of bright meteors was also still quite high.

Thursday, May 10

With two nights of observations now waiting to be written up, it was imperative that we make this our first job after daylight. By the time we had finished, it was almost lunchtime and we were anxious to get moving. We visited the beautiful town of Broome and then continued to Eighty Mile Beach, 350 kilometers south, where we planned to camp for our final night's observing. Arriving around dusk, we set up camp and ate dinner beneath a brilliant waxing Moon that bathed the surrounding countryside with an eerie glow. On many occasions, such a Moon is cursed by meteor observers since its bright, pearly glow completely overpowers that of a meteor, rendering all but the most brilliant ones invisible. On this occasion, however, it was a friend. Walking alone along the beach, listening to the restless waves which sparkled in the moonlight in a way known only to the nocturnal wanderer, everything seemed beautiful and peaceful. It gave me an opportunity to reflect on our expedition and put it into perspective. We had gained much valuable data on the Eta Aquarids and other showers we observed. But compared to what we do not understand about our home planet Earth, let alone the vast universe surrounding us, the knowledge we had gained seemed infinitesimally small.

Mankind can do what he may, but the stars will always be there, serenely pursuing their allotted paths and challenging man with new mysteries to unravel and new wonders to enthrall. With reluctance, I crawled into my sleeping bag to sleep until moonset.

At 2:30 a.m., the alarm rang and we crawled outside. By 3 a.m., we were ready to commence observing. Total sky rates were still quite high, in excess of one per minute, though the number of Eta Aquarids was noticeably lower. A brilliant yellow Eta Aquarid burned across the sky, leaving a persistent train that lasted many seconds. Many faint meteors were observed, then another brilliant Eta Aquarid — orange this time — was seen. All too soon it was over and the Sun was rising. Between us we had added another 288 meteors to our tally, which now exceeded 4,000.

We wrote up the observations, packed away camp, and headed for Karratha, located 500 kilometers away. There would be no more observing of the 1984 Eta Aquarids. The waxing Moon would see to that.

Arriving in Karratha, Christian and I unpacked the car and said goodbye. Then it was off for an interview with the *Hamersley News* and later a discussion of how the trip went with some of the people who helped organize it. Finally it was time to leave Karratha and begin the long trek home. In a few days, my leave would be over and I would be back to the grindstone. Months of work lay ahead in analyzing the data, but now was a time to enjoy the scenery and give thanks for a successful expedition.

I had to wait 10 years before my odyssey became a reality. I wonder if I shall have to wait as long to visit Wolf Creek again?

Postscript — On arrival at Perth, I called on several friends who had planned to observe the Eta Aquarids. What they told me made me very thankful that I had been able to go to Wolf Creek. Apparently, clouds and rain had almost totally obliterated the meteor shower from the southwestern region of Western Australia, thus making our observations all the more valuable. Most people were rather envious of what I had observed.

I suppose I *should* feel sorry for them . . .

Maurice Clark
Rolystone, Western Australia

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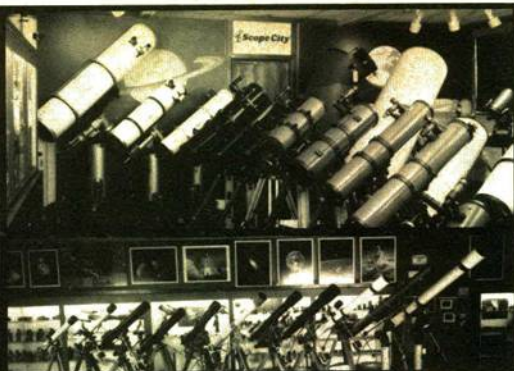
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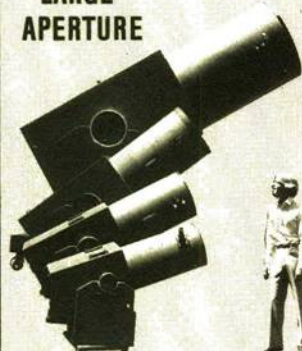
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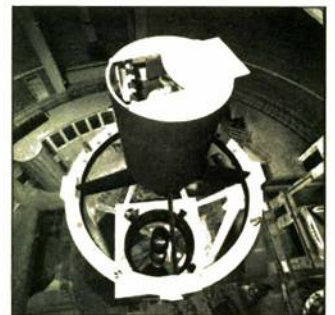
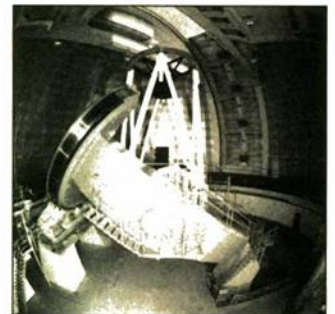
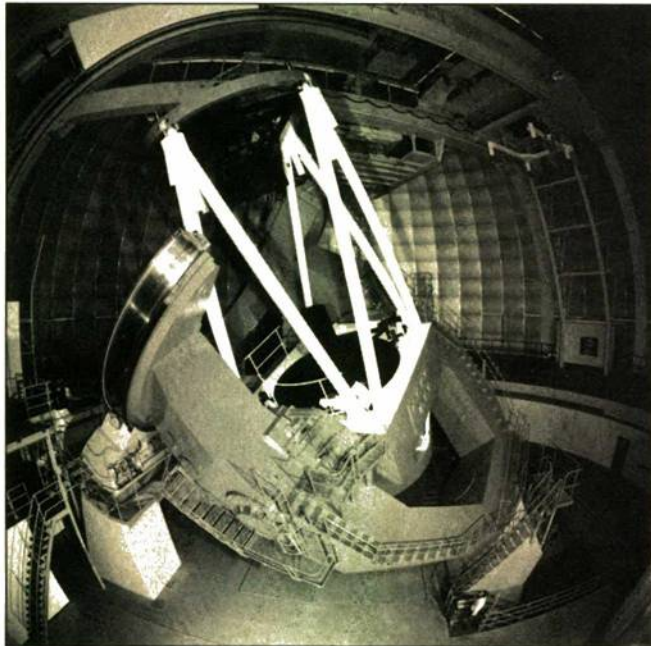


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ASTRONOMY

In Focus

Selling Halley in 1910

Sir / The introductory paragraphs of Clive Gibbons' "Selling Comet Halley" (ASTRONOMY, June 1985) contain several misconceptions regarding Halley and the public in 1910.

First, city dwellers had to battle with air and light pollution resembling today's 75 years ago — and many were disappointed with Halley's "performance" afterwards. The British science journal *Nature* warned in May: the comet "is by no means an easy object, especially for town dwellers."

Later, in June, when the Halley craze was fading, it noted: "as a popular spectacle" the comet "has been somewhat of a failure . . . some amount of resentment has been expressed in the popular press at the feeble appearance of the famous comet, but it should be clearly understood that it is our hazy summer skies and the brightness of our northern twilight that are to blame" (*Nature*, June 2, 1910, p. 409).

Many popular science writers, especially in Germany, also blamed the severe light pollution over populated areas as the reason for the comet's "failure," while it was a "glorious sight" in rural areas and in the tropics. It is very likely that exactly the same will happen now.

The other error in the article concerns "the selling" of the comet in 1910. In fact, there were attempts to advertise small scopes "to see THE comet," but with a big difference: they were cheaper. Back then a refractor sold for \$30 to \$100; these days. . . !

Daniel Fischer
Koenigswinter, West Germany

Red Dwarfs Live Forever

Sir / What is a "red dwarf" star? In your article on globular clusters (May 1985), the last paragraph states that red dwarfs have existed for 15 or 20 billion years and will continue to exist

for billions of years to come. This seems like a long lifespan for a star.

Mark Wetherell
Attleboro, MA

— *Red dwarf is the name given to a star that has between about 0.06 and 0.3 times the mass of the Sun. These are the smallest full-fledged stars that exist, and are probably the most numerous in the Galaxy. The pace of a star's evolution, its luminosity, and its lifetime are largely determined by its mass. Small-mass stars such as red dwarfs burn cool (which is why they are red in color) and use up their nuclear fuel very slowly. Therefore, they have extremely long lives.*

Stars Above

Sir / I would like to relate to you and the readers of your fine magazine how I came to enjoy the beauty of astronomy.

It was a hot — no, make that very hot — night in north central Texas. We were suffering through the second month of over 100° temperatures and rarely did the mercury dip below 80° during the night. It was one of those nights that drove me outdoors in hopes of a cool breeze. I took a blanket from my car and spread it on the grass to keep the chiggers from carrying me to Oklahoma. (What could be worse?) I then lay down and was just getting comfortable when I noticed how dark the sky was. There was no Moon and the stars were bright against an inky black background.

I was awed by the number of stars that could be seen. I began to look around and noticed a couple of constellations that I recognized. I was familiar with only a few anyway, and they happened to be the two in the sky that night: Scorpius and Ursa Major.

What happened next changed my thinking about astronomy for the rest

of my life. I began to think that if I could see all those stars with my naked eyes, what would it be like if I looked through a pair of binoculars? Would they look bigger or closer? Would they look brighter? I quickly rose and went to the car to retrieve my 7x35's — nothing special, just a pair of K-Mart's best. I went back to my blanket, lay down, and put the binoculars to my eyes.

Wow! Oh, wow!

That's about all I could say for at least an hour.

I was looking in the direction of Scorpius and Sagittarius (I didn't know it was Sagittarius at that time) and the other parts of the Milky Way arm we see in that direction. I was utterly amazed. I had no idea there was so much up there. I saw wispy cloudlike areas, bunches of stars in clusters, and so many stars in some areas that they couldn't be resolved into separate stars. I saw double stars, specifically Epsilon Lyrae. I was hooked. I had to find out what those "things" were I was looking at.

The next day I bought Patrick Moore's *Pocket Guide to Astronomy*. I quickly learned the names and shapes of the constellations, and the names of stars. I found out those wispy areas were nebulae and the bunches of stars were open clusters.

Today, five years later, I still consider myself an infant in astronomy. I eagerly await each new ASTRONOMY and purchase as many books on astronomy as I can afford.

I don't have a telescope, so for now I use binoculars. I have three different sizes: 7x35, 7x50, and 8.5x44. The 8.5x44's are an extra-wide-angle pair and give splendid views of the star clouds in Sagittarius. I feel like I'm almost ready to buy a quality telescope and start searching for the deep-sky objects I've been reading about. The binoculars are fine, but I'm starting to get "aperture fever." Until I get that

scope, however, I'll continue to observe with my binoculars and be amazed at the starry sky above me.

Ricky D. Hamel
Atlanta, GA

Finding the Stars

Sir / I have tried for many years to identify stars in the night sky without any progress — they were mysterious points of light with names that I didn't know — until tonight. I waited 'til it got dark and then sat outside with my June copy of *ASTRONOMY*. Now I'm sure I've recognized Vega, and from there Altair. At last, after years of frustrating searching, I know where I am. Thank you. The night sky will no longer be full of enigmatic strangers; there are now a few friendly faces and, with luck, in the future there will be more.

Jill VanHoute
West Copake, NY

— We're delighted that our new *Star Dome* has worked so well for you. A number of long-time *ASTRONOMY* readers have noticed our production difficulties with the "Dome" — especially print too dark to read. We think we have these problems under control now.

We'd like to remind those who still favor the old *Star Dome* that those maps are available in our water-resistant spiral-bound constellation guide *The Star Book*. Our 24" x 36" color poster *The Starry Sky* uses the base map from the old *Star Dome*. If you're handy at making things, it's possible to construct a two-foot diameter planisphere by cutting out and mounting it behind an appropriate oval mask.

Photo Help, Please!

Sir / I recently bought a Comet Catcher to follow Halley's Comet. Right now I have it mounted on a Slik photo tripod, money being a little short. Eventually, I want to purchase the equatorial mounting, clock drive, etc.

I was wondering if I could take pictures through the scope with the equipment I have. Any advice you can give will be appreciated.

Thomas Fertal
Kingston, PA

— For most through-the-telescope astrophotography, you need an adapter that couples your SLR camera body to the telescope's focuser. These are commonly sold by accessory dealers — see the advertisements in *ASTRONOMY*.

But with the adapter in hand, you are still fairly limited in what you can photograph. On an ordinary photo

tripod, the Comet Catcher becomes an alt-azimuth telescope. These are fine for sweeping the skies visually.

However, such a telescope can be used for astrophotography only when the exposure times are short enough that you don't have to track on the object. In practice, this means you are limited to photographing the Moon, the Sun (suitably filtered), and perhaps Venus and Jupiter — all objects bright enough to be captured with a "snapshot." Anything dimmer calls for an extended exposure, which an alt-az mounting rules out.

We suggest you spend lots of time looking through the scope first. Become familiar with the sky and what it contains. Then get an adapter and try some snapshot astrophotos. Later, after you have an equatorial and some extra astrophotographic equipment, you can try for the fainter stuff. Remember, Halley's Comet will be a stirring sight, but there'll be other comets coming along in the years

ahead, too. Besides, comets hardly scratch the surface of all there is to see out there!

Sighting Sirius

Sir / Back in the February issue, an Englishman wrote about sighting stars late in their apparitions. He mentioned that last year he spotted Sirius on April 30th from 51½° north latitude. I'm responding to his request for late sightings from the United States.

I currently live 17 miles west of downtown Chicago at 42° north latitude. About 45 minutes after sunset on May 21, 1985, I saw Sirius about 5° above the western horizon — first with 7x35 binoculars, and then with unaided eyes. It was just detectable as a slight glimmer in the twilight.

By the way, has anyone ever tried to catch the Dog Star during daylight with 11x80 binoculars?

Robert F. DeStefano
Lombard, IL

Behind the Scenes

A New Era Begins for *ASTRONOMY*

In the March *Behind the Scenes*, I announced that AstroMedia Corp., the publisher of *ASTRONOMY*, would soon be purchased by Kalmbach Publishing Co. of Milwaukee. On August 1, the sale finally went through: *ASTRONOMY*, *Odyssey*, *Telescope Making*, and *Deep Sky* magazines are now owned and published by Kalmbach. Our new owner is also the publisher of *Model Railroader*, *Trains*, and *FineScale Modeler*, all well-respected hobby magazines in their fields.

As I explained back in March, *ASTRONOMY* readers will hardly know the difference — your magazine will continue to arrive on time each month, full of helpful hobby articles and features. Of course, we have some big ideas in store for *ASTRONOMY* — so keep your eye on us. We plan to get bigger and better!

This month we say good-bye to one of our long-time *ASTRONOMY* staff members. Katherine Bond, our Managing Editor, is leaving *ASTRONOMY* to manage Bruce Bond's Artworks, her husband's art/illustration business. Kate started as *ASTRONOMY*'s Editorial Secretary in October 1975, some four months before I joined the staff as Technical Editor. (Neither of us can believe that was over ten years

ago!) A natural-born organizer, Kate has kept us editors in line for the last six years. In her place, we've hired Stephen Cole, whose name will appear instead of Kate's on the masthead next month.

Finally, our feature this month concerns all of you: it's about light pollution — and politics. I've been interested in light pollution for a long time, dating back to the early 70s when Rob Pike (the brains behind the computer-generated light pollution map on pages 16 and 17) and I investigated light pollution in southern Ontario. We derived a mathematical model to explain the spread of light and computed a map based on the model. (The results were published in the *Journal of the Royal Astronomical Society of Canada*, June 1975.)

Well, that was the easy part. Fighting light pollution is very difficult — and very discouraging — especially for isolated groups of amateurs battling city hall. Nonetheless, I urge you to keep at it.

Sincerely,



Richard Berry
Editor-in-Chief

ASTRONOMY Reviews

Technidol LC Developer

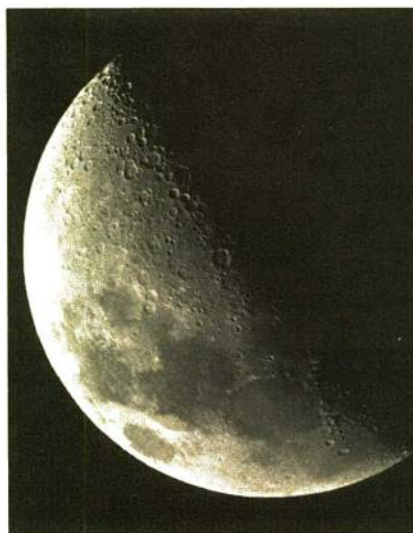
Eastman Kodak Company
Rochester, New York 14650
\$4.20 for three 16-ounce packets

Technidol LC is a special low-contrast developer that gives normal (pictorial) contrast with Kodak's Technical Pan 2415 film, an intrinsically high-contrast emulsion. It uses phenidone as its only developing agent and is intended to replace POTA, a developer that users have had to mix for themselves since it has never been manufactured commercially. Technidol LC is *not* the same as Technidol Liquid, which achieves similar results with different developing agents.

Technidol LC is a compensating developer. That is, it is designed to be completely exhausted by developing one roll. The exhaustion takes place more quickly over heavily-exposed areas than over the more lightly-exposed ones. This limits highlight densities while allowing shadows to develop fully; the result is very much like what you get from careful dodging under the enlarger, except that the developer does it for you automatically. This "automatic dodging" helps bring out fine detail. In fact, small details 0.05 mm wide on the negative are rendered with as much as 60% more contrast than larger features of comparable brightness.

Like all compensating developers, Technidol LC requires carefully controlled agitation. (Too much agitation can prevent the automatic dodging from taking place.) Kodak recommends that you fill the tank with developer, then lower the loaded reel into it in total darkness (so that the film comes into contact with the developer essentially all at once) and put on the lid. Agitate by inverting the tank a few times at 30 second intervals. I followed these instructions and had no problems with uneven development.

What's it good for in astrophotography? Technidol LC is ideal for lunar photos. The accompanying picture is an example; it was printed on Polycontrast II Rapid RC



First Quarter Moon: A ¼-second exposure at the prime focus of a 5-inch f/10 Schmidt-Cassegrain on Technical Pan 2415 film developed 13 minutes in Technidol LC at 72° F. The original print is an 18.5x enlargement on Polycontrast II Rapid RC with no filter and no dodging.

with no filter and no dodging or burning in. My terrestrial photographs with 2415 and Technidol LC were also outstanding. The enhancement of contrast in fine detail gives pictures an unusual glowing quality. And, as we all know, Kodak's 2415 is practically grainless in enlargements up to 25 times. (When developed in Technidol LC, its effective ISO/ASA rating is 25.)

Planetary photographs on Technical Pan 2415 can be developed in Technidol LC, but a higher-contrast developer such as HC-110 is preferable because contrast usually improves the pictures and the effective speed is much higher. Deep-sky photographs normally require maximum speed and contrast — which Technidol LC certainly does not give.

I haven't tried Technidol LC with hypersensitized film, but my experience with other phenidone-based developers

suggests that fog would be excessive. However it may be practical to use Technidol LC, like POTA, with conventional films such as Tri-X when you need extreme exposure latitude, as in solar eclipse photography. Overexpose generously, then print the resulting low-contrast negative on high-contrast paper.

A package of Technidol LC contains three packets, each of which makes enough working solution to develop two rolls of 35 mm film. (Technidol LC is not recommended for larger formats.) The catch is that the working solution must be used within 24 hours. Unless you expose or process your rolls of film in pairs, you'll seldom get to develop more than one roll with a single packet. This makes Technidol LC one of the most expensive developers on the market — up to \$1.40 per processed roll. Still, after getting results like those shown here, I'm convinced that the quality is worth paying for. *Michael A. Covington.*

Sky Travel

software for Commodore 64
tape or diskette, no price given
Commodore Educational Software

Indoor Astronomy

software for Commodore 64
2 diskettes, no price given
Astro Link

Astro Positions

Pierre Brind'Amour
software for Commodore 64
diskette, \$49.95
Microtechnic Solutions, Inc.

Astronomy, more than nearly any other hobby, lends itself to computing. Accordingly, a sizable base of microcomputer programs which locate the stars and planets has become available. In this review, we consider three programs for an impressive "low-end" home computer, the Commodore 64. Since we evaluated the programs using a

system with a black and white monitor, we missed the colorful screens this computer generates.

Sky Travel is a friendly program. We followed the instructions, inserting the diskette and typing LOAD "*"8,1. After a short wait, the screen displayed the images of an open notebook with the name of the program, then a series of welcoming messages. It told us to "please be patient . . . we're loading a big chunk of the universe into a very small computer." After the program has loaded, it computes and displays the night sky for January 1, 1985 with Leo prominently overhead.

The power of *Sky Travel* lies in its ability to display a sky window for any time and place between 9999 B.C. and 9999 A.D., with planetary positions accurate to a few minutes of arc within several hundred years of the present. The screen shows a view 72° across, with optional constellation lines, planets, and deep-sky objects. A bar down the right side of the screen shows the date, time, and location of the cursor in altitude, azimuth, r.a., and dec.

Making full use of this capability requires input from the user. To select our location on Earth, we pressed the f1 key to select the MAP option. A Mercator projection of Earth appeared with the cursor centered on New York City. We lost no time in moving ourselves to

Milwaukee, then pressed f1 again and selected SET to enter the time and date. We moved the cursor to the month, day, year, hour, and minute, raising or lowering each by pressing the + and - keys. Pressing f2 allowed us to select the SKY option and pressing [return] started the machine computing positions of the Sun, Moon, and all eight planets for our given date. Fifteen seconds later, the night sky snapped onto the screen. We could view different parts of sky by pressing N, E, W, or S and after waiting six seconds, the screen would show a new view of that part of the sky. By moving the cursor to the edge of the window, we could make the computer slew the view over — once again, with a six-second wait.

We next looked at the options available with the f3 key. We could turn on or off the constellation lines or names, deep-sky objects, or, more intriguing, turn the tracking on or off. Tracking could be set to run in "real time," either forward or backward, at rates up to 64 times that of real. With tracking on, the stars rose in the east and set in the west as the clock ran forward. In addition, the program recalculated the positions of the Sun, Moon, and planets every few "hours." The Moon rose at 1:36 a.m., just below the Great Square of Pegasus, and the sky brightened somewhat. Eventually, around 5 a.m., the sky brightened and the Sun

rose into the daytime sky.

In addition to the SKY mode, *Sky Travel* can display the sky in "chart" mode, a north-at-top black and white with the stars on a coordinate grid. In any of these modes, we were able to call up a description of the object by placing the cursor on an object and pressing the f7 key. The bright star in Corona Borealis, according to the program, is HD 139006. Also called Gemma or Alphecca, it is magnitude 2.2, of spectral class A0, and 72 light-years distant. Pretty impressive.

In addition to these features, *Sky Travel* also can FIND objects using the f5 key. Since the program can compute the position of Halley's Comet, I decided to check its visibility from Tahiti on March 15, 1986. We first went to the map and moved the cursor to 17°S and 149°W longitude, then set the date and guessed that 5:00 a.m. would be a good observing time. Pressing f1 and selecting SKY mode soon brought a view of the western sky. We pressed E to view the eastern sky and — there was the comet! Using the f5 key, we then found the Moon 79° below the horizon! The Sun was 14° below the horizon — a bit too bright for comfort, so we set the time to 4:40 a.m. and checked the Sun again. It was now 19° 41' below the horizon. Finding the comet again showed that it will be 37° above the horizon at azimuth 105°, a little below

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and to the left of Sagittarius, tail pointing straight up from the horizon, with Jupiter just rising and Mars straight above it.

Hitting shift-P started our Gorilla Banana printing a paper copy of the screen. This process takes two or three minutes, but getting "hard copy" to study is worth the wait.

All told, *Sky Travel* is interesting, powerful, and capable software. Although the representation of the sky is rather crude, the program is good enough not only for education, but also to answer real questions about the visibility and location of sky objects.

Indoor Astronomy is, by contrast, a program to generate and print star charts. It comes with several dozen presaved screens, a stellar database that includes several thousand stars, and a list of some 2,000 deep-sky objects.

While Loading the program was in progress, a picture of a starry sky, house, and a figure with a telescope appeared. After a minute or so, the screen cleared and presented the *Indoor Astronomy* menu. The options are: finderscope, observe, re-display, save, load, see directory, get joystick editor, printout, include deep-sky objects, set monitor scale, format a new diskette, change colors, and exit. Pressing a single letter key begins each action.

The observe function is the primary activity; "O" picks this mode. Entering the central r.a. and dec. plus a "magnification" starts the system reading stellar data off the diskette and drawing a star map on the screen. It takes two or three minutes to search through enough of the database to fill the screen.

Once you've created a star chart, you can press the "@" key to redisplay it at a larger scale, "*" to rotate it in 30° increments, or "E" to return to the menu to print it or save a copy of the screen to the diskette. At 1x magnification, the screen is about 60° across — not quite wide enough to accommodate both Scorpius and Sagittarius at the same time. A screen centered on Orion's belt just includes the Hyades and Sirius at diagonally opposite corners of the screen.

The charts look quite nice on the monitor. Stars are graded into a magnitude scale with spikes sticking out of the brighter stars. We found by setting the monitor's contrast high and turning the brightness down, then squinting heavily, the screen looked like the sky on a gloriously clear night. The instructions and legend at the top and bottom of the screen were annoying, but we found that by first magnifying the screen and then returning to the original scale (by means of the "-" key) lost them.

Once you've "observed," magnified, rotated, printed, or saved a screen, you can edit it. We were unable to try this because our Commodore 64 didn't have a joystick. However, we examined a number of the scenes included on the

second diskette. These include Orion over a winter snow scene, numerous constellations with colored stars, and digitized images of deep-sky objects such as the Ring Nebula in Lyra.

The manual is full of all sorts of ideas for using the program, from learning the constellations, making charts, and hunting for comets (by plotting them on charts made with the program) to plotting the paths of the planets (as with comets). Although it is very enthusiastic about what the program can do, the manual is not terribly specific about what the program actually does or how to do it. *Indoor Astronomy* is, nonetheless, fun to mess around with.

Astro Positions is the most "technical" of the programs considered here. It computes ephemerides of the Sun and stars accurate to a second of arc, of the Moon and planets to one minute of arc, and Pluto to lower precision. According to the manual, the program uses the math routines of the *Astronomical Papers Prepared for the American Ephemeris and Nautical Almanac*, Vol. 6, Part 1 (1898), and uses "rectified elements and fundamental arguments from the *American Ephemeris and Nautical Almanac*, 1978."

So much for the technical stuff. The program is quite large and takes a long time to load, during which the screen flashes different colors (different shades of gray with our monochrome monitor). The main menu asked that we enter a selection. "0," the "astrology option," caused us to raise our eyebrows a bit. We selected, instead, data for Jupiter, option 7.

The program then asked for a date, time, time zone — all the usual questions. The output of the program gave the orbital position of Jupiter, its equatorial coordinates, and the positions of the Galilean satellites.

At this point, we were given three options: to compute another celestial body for the same time and circumstances, to start over again, or to quit. We picked option 1 for Mars. Without needing us to enter time and circumstances, the program took roughly two seconds to output two screens of information about Mars.

At this point, having seen the program do its thing twice, we tried the astrology option. (Here, we reveal that "we" is "I" with a single horoscope to cast.) We entered the date, time, latitude, and longitude of our place of birth. The computer computed for 36 seconds, then revealed the planetary positions at the time of our birth by zodiac sign, degrees, and minutes. After printing the page, it then computed our house cusps and three screens-full of aspects. With this information at hand, we turned to the manual to cast our horoscope.

All three programs did more or less what they claimed to do, were easy

enough to run, and we were able to use them properly. *Astro Positions* is really not much use to an amateur astronomer because it apparently can't produce an astronomical summary of all the planets, although it can produce an astrological summary. To see what all of the planets were up to, we had to run them individually.

Indoor Astronomy is a clever program for printing out star maps and other astronomical graphics from a disk-based data file. However, it is difficult to see what this program offers that an atlas such as *Sky Atlas 2000.0* does not — except that interaction with a computer is considerably more engaging, if ultimately less rewarding.

Sky Travel emerges the clear winner. It will calculate solar, lunar, and planetary positions over a long span of time, follow Halley's Comet through the 1985/86 apparition, and display how the sky appears at any time over a 20,000-year span from any place on Earth. This has real utility. With the real-time clock running, the sunrise/sunset sequences are almost too cute, but they do mimic the very real effects of twilight and dawn — and we did enjoy watching the show. *Richard Berry.*

Dismantling the Universe

Richard Morris

224 pages, paperback, \$6.95

Simon & Schuster (1984)

Subtitled "the Nature of Scientific Discovery," this book explores how science actually gets done — which is usually very different from what the general public conceives scientific method to be. (For example, intelligent non-scientists are often shocked to learn that science, unlike politics, does not give all ideas equal time, and that new ideas always carry the burden of proof.) Besides exploding a lot of mythology, Morris does an entertaining and readable job of conveying the flavor of scientific research to the lay reader.

Time's Arrows

Richard Morris

240 pages, hardcover, \$17.95

Simon & Schuster (1984)

What is the nature of time? Writing for a popular level audience, Morris explores this question chiefly as it applies to western scientific thought. Although he concludes that time probably runs in a cyclical fashion (from Big Bang to Big Crunch to Big Bang again), he stresses that this circularity isn't the same as that found in oriental thought: "It is clear that the ancient idea of cyclical time was derived from the observation of cyclical processes in nature . . . Modern conceptions of cyclical time, on the other hand, are based on sophisticated theories about the nature of the universe."

**Handbook for Astronomical Societies
1984/85**

Brian Jones, ed.

68 pages, paperback, £ 2.20

Federation of Astronomical Societies
(1984)

[Publisher's address: 47 St. Blaise Ct., off
Manchester Road, Bradford, West
Yorkshire BD5 0QE, England]

Besides a listing of U.K. astronomical societies, this pamphlet contains four articles (three on building telescopes and observatories), and lists of periodicals, equipment suppliers, places to visit, and so on. Though it is intended for U.K. amateur astronomers, any amateur who plans to visit there would find a copy useful.

The Unexpected Vista

James E. Trefil

209 pages, paperback, \$7.95

Collier Books (1985)

Physicist Trefil poses simple-looking questions, such as "Why won't a magnet pick up a penny?", and uses the answers to explain to the general reader how the entire physical world is interrelated.

Check a Possible Supernova, Set 2

Juhani Salmi

40 cards, spiral bound, no price given

JS Observatory (1985)

This set of 40 cards extends the author's 1984 publication of galaxy photographs for use as supernova finding charts. Covered in the second set are objects such as NGC-205, M-77, M-95, M-96, M-109, and IC 342.

Supernovae as Distance Indicators

H. Araki, et al.

226 pages, softcover, \$13.70

Springer-Verlag (1985)

One of a series of "Lecture Notes in Physics," this typescript volume contains proceedings from a workshop on supernovae held at the Harvard-Smithsonian Center for Astrophysics in 1984. Among the contributors are Allan Sandage, Gustav Tammann, Craig Wheeler, Robert Kirshner, and Brian Marsden.

The Big Bang and Georges Lemaitre

A. Berger, ed.

420 pages, hardcover, \$59

D. Reidel (1985)

The Big Bang and Georges Lemaitre is the proceedings from a symposium held in Louvain-la-Neuve, Belgium, in honor of cosmologist Georges Lemaitre. Included are topics spanning cosmology, from the Big Bang to quasar energy

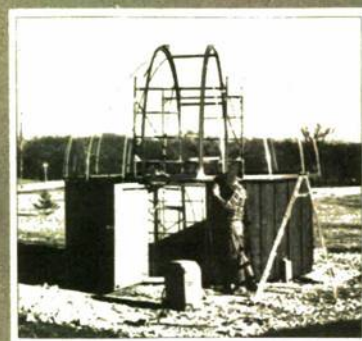
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production to time to nucleosynthesis. Also included are chapters on celestial mechanics, the structure of the universe, and a summary of Lemaitre's achievements.

The Photochemistry of Atmospheres

Joel S. Levine, ed.

518 pages, hardcover, \$79.50
Academic Press (1985)

Subtitled "Earth, the Other Planets, and Comets," this book examines the chemistry of various atmospheres in the solar system and includes a chapter on comets.

Jane's Spaceflight Directory

Reginald Turnill, ed.

311 pages, hardcover, no price given
Jane's Publishing (1985)

Jane's Spaceflight Directory is an encyclopedic guide to spacecraft flights, and historical feats.

Interstellar Chemistry

W.W. Duley and D.A. Williams

251 pages, hardcover, \$49.50
Academic Press (1985)

This volume, written at a level appropriate for advanced undergraduate chemistry majors, or as a graduate-level text, begins by examining the types of molecules found between stars and then moves on to discuss basic chemistry, ionization, photophysics of interstellar molecules, and molecular hydrogen. A concluding section summarizes the present state and future prospects of chemistry between the stars.

Astrophoto VI

John Sanford, ed.

52 pages, paperback, \$10
Orange County Astronomers (1985)
[Order from: OCA, 2215 Martha Ave.,
Orange, CA 92667]

This anthology of papers given at an amateur astrophotographic seminar in March 1985 contains discussions of such topics as astrophotography with 3M 1000 film, a thermoelectric cold camera, latensification and other alternatives to gas hypering, and processing for maximum speed. It has many black and white illustrations.

Time Gate

Charles Pellegrino

275 pages, paperback, \$16.95; hardcover,
\$24.95

TAB Books (1985)

Living up to its subtitle "Hurtling Backward Through History," this book

surveys the entire history of the universe in 250-odd pages. Starting in the present and with each step backward in time being twice the previous, the author reaches Neanderthal man by page 104, the death of the dinosaurs by page 185, and 8,000,000,000 B.C. by page 249. Two pages after that, the reader is in the "Jiffy Era" (a jiffy, as in "I'll be with you in a jiffy," is 10^{-23} second), and the only end in sight is that of our knowledge.

Science Goes to the Dogs

Sidney Harris

110 pages, paperback, \$7.95
ISI Press (1985)

Sidney Harris has long been known as the "scientific cartoonist" — his drawings appear in *American Scientist*, *Science* 85, and *The New Yorker*, among others. In this book, Harris looks at the physical and social sciences, mathematics, literature, and the arts with, er, a doggedly funny perspective.



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Microcomputer Control of Telescopes

Mark Trueblood and Russell Genet

377 pages, softcover, no price given
Wilmann-Bell (1985)

This volume outlines hardware and software requirements for computer-controlled telescopes of various sizes. Topics include telescope control systems, pointing and tracking, software design, and examples of automated telescopes.

The Joy of Gazing, 2nd ed.

David H. Levy

110 pages, softcover, \$6.95
Royal Astronomical Society of Canada
(1985)

The Joy of Gazing is a personal account of observing the sky from a long-time star watcher, who offers advice on choosing a telescope, and observing the Sun, Moon,

solar system members, and deep-sky objects.

The Hidden Universe

Michael Disney

257 pages, hardcover, \$17.95
Macmillan (1985)

By investigating various topics in cosmology — such as a galaxy's mass, galactic distances, Zwicky clusters, galaxy rotation, and quasars — the author proposes ideas for the so-called missing mass in the universe.

General Relativity and Relativistic Astrophysics

Norbert Straumann

459 pages, hardcover, no price given
Springer-Verlag (1985)

Intended for graduate students, this textbook is divided into three parts. The first examines differential geometry — tangent vectors, tensor fields, oriented manifolds, and so on. The second explores theoretical aspects of general relativity. The last applies relativity to physical problems in astrophysics — neutron stars, rotating black holes, and binary X-ray sources.

On Civilized Stars

Joseph F. Baugher

260 pages, paperback, \$9.95; hardcover,
\$21.95
Prentice-Hall (1985)

Subtitled "The Search for Intelligent Life in Outer Space," Baugher's popular-level book examines the factors which we think led to the rise of intelligent life on Earth, and then explores the chances for life elsewhere.

Handbook for Space Colonists

G. Harry Stine

273 pages, softcover, \$11.95
Holt Rinehart Winston (1985)

Subtitled "Everything You Need to Know When Planning Your First Journey Beyond Earth's Atmosphere — What to Expect and How to Prepare for It," this work discusses living, eating, sleeping, playing, working, and traveling in space — in encyclopedic form.

Astronomy: The Evolving Frontier

Michael Zeilik

494 pages, hardcover, no price given
Harper & Row (1985)

This is the fourth edition of a college textbook for non-science majors. It covers the subject from a historical perspective, and then deals with the solar system, stars, and galaxies.

A Matter of Choice

Joe Caruso is the chief telescope operator at Wesleyan University in addition to teaching astronomy at the University of Hartford. He uses the 20 inch Alvin Clark refractor to precisely determine trigonometric parallax for stars in the solar neighborhood. With access to some of the world's most sophisticated astronomical instruments, Joe's telescope of choice is the Bausch & Lomb 4000 for leisure time observing. The 4000 incorporates the quality and many features found in larger telescopes. From his home in the city, Joe reports no difficulty acquiring the 12th magnitude G8 subdwarf in the Pleiades. In addition to the fine optics and mechanical aspects of the 4000, Joe considers the portability a very useful feature.



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Hurrah for the Northern Sky!

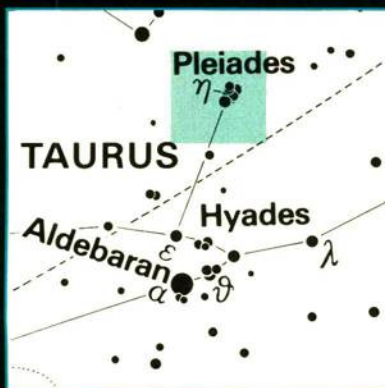
by
Robert Reeves

At some point or other, every serious astrophotographer has heard the Fantastic Tales of the Southern Sky. These tales are usually told by professional astronomers, recent visitors to the southern hemisphere, or armchair astronomers who've just read all of *Burnham's Celestial Handbook* or *Hartung's Astronomical Objects for Southern Telescopes*. The stories are diverse and wide-ranging, but they all serve the same purpose: to make photographers stuck in the northern hemisphere seethe with jealousy because "all of the really good stuff lies in the southern sky."

It's true that some of the largest, brightest deep-sky objects are invisible from mid-northern latitudes — both Magellanic Clouds, globular cluster 47 Tucanae, Eta Carinae Nebula, and the giant open clusters NGC-3532 and IC 2602, to name just a few. But despite this, the Fantastic Tales of the Southern Sky are an astronomer's version of a fishing story — remember, "the grass is always greener . . ." Fed up with statements about the glorious southern hemisphere, I decided to make an album of deep-sky objects in the good old northern sky, some of which are reproduced here.

Contrary to the Fantastic Tale-tellers, the northern Milky Way contains plenty of detailed, spectacular deep-sky objects. The North America Nebula in Cygnus, for example, is a huge emission nebula visible as a diffuse patch near Deneb on dark nights. A 15-minute exposure shows its shape well, which is remarkably similar to the continent of North America. On all sides, intricate dark nebulae surround and define the ruddy hydrogen gas that forms this distinct outline. Also in Cygnus is the unique Veil Nebula, the sky's brightest supernova remnant. Appearing as a broken circle of light that covers over 5°, it is composed of wispy filaments of the shredded star which created it 20,000 years ago — all set against a rich background of stars.

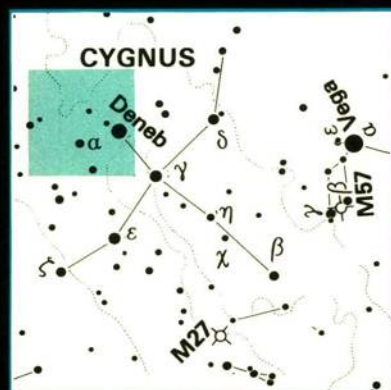
Just south of the Garnet Star, Mu (μ) Cephei, is the huge emission nebula IC

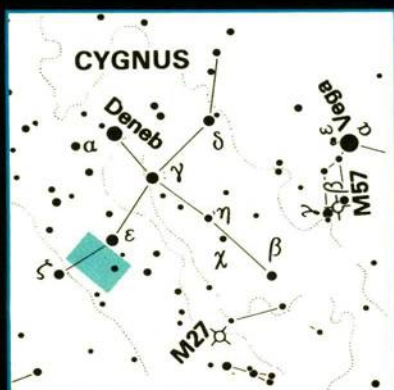
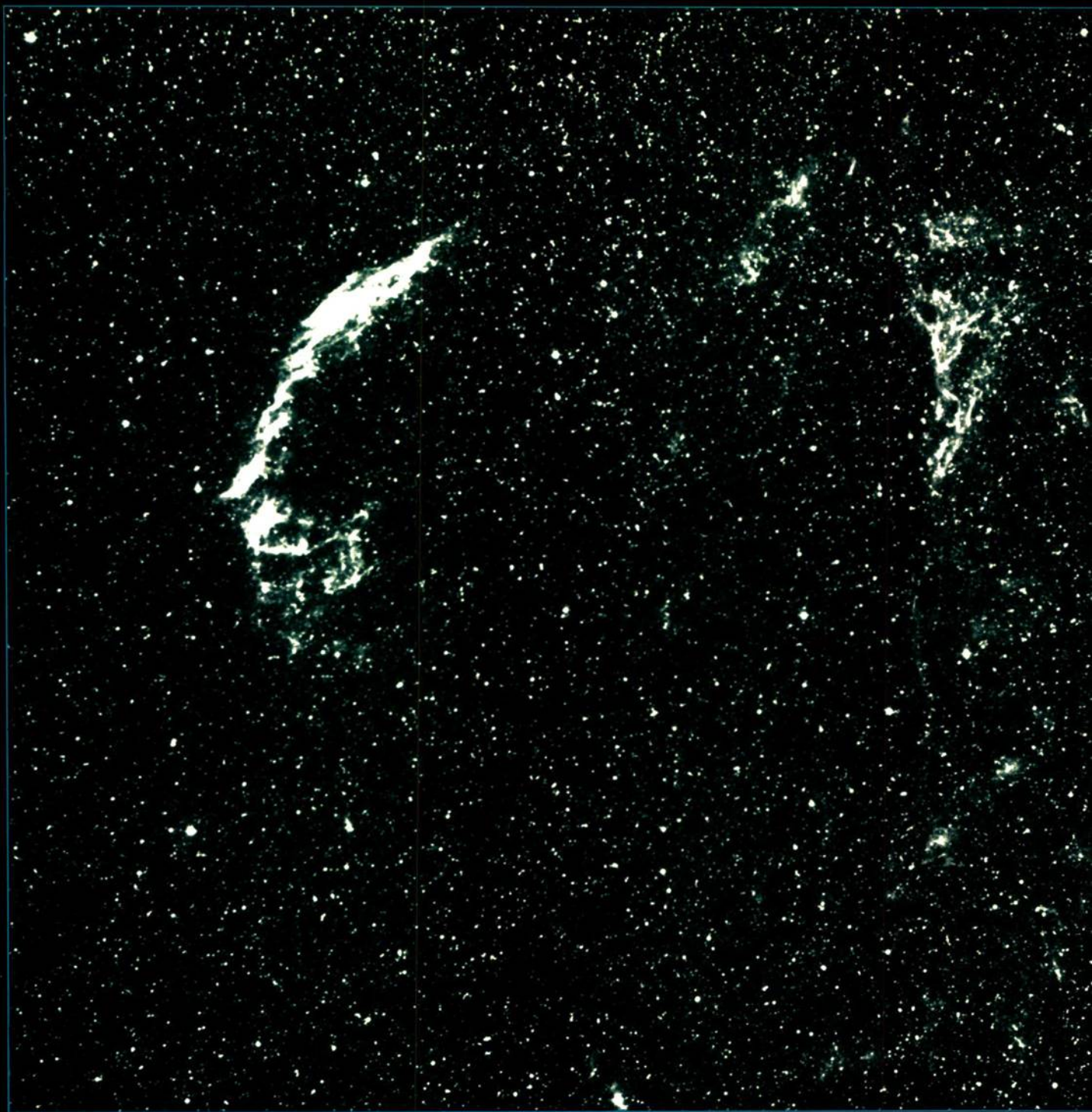


The Pleiades Cluster in Taurus is a favorite target for astrophotographers: its brilliant bluish-white stars spill over an area covering 2°. Photo by Mark Coco; 135mm f/2.8 lens, 30-minute exposure on Ektachrome 400.

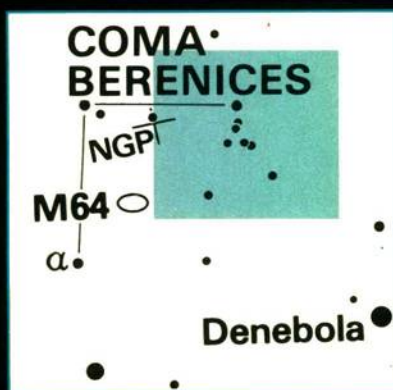


Visible to the naked eye on dark nights, the huge North America Nebula in Cygnus is one of the northern sky's most complex emission nebulosities. Photo by Mark Coco; 135mm f/2.8 lens, 30-minute exposure on Ektachrome 400.



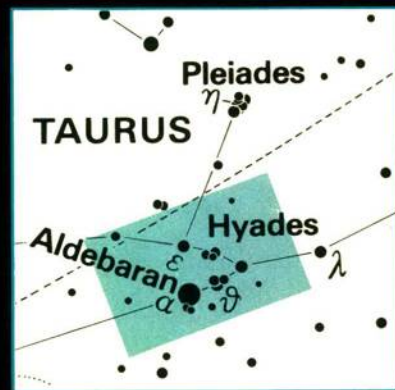


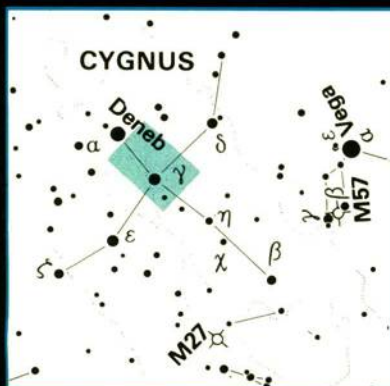
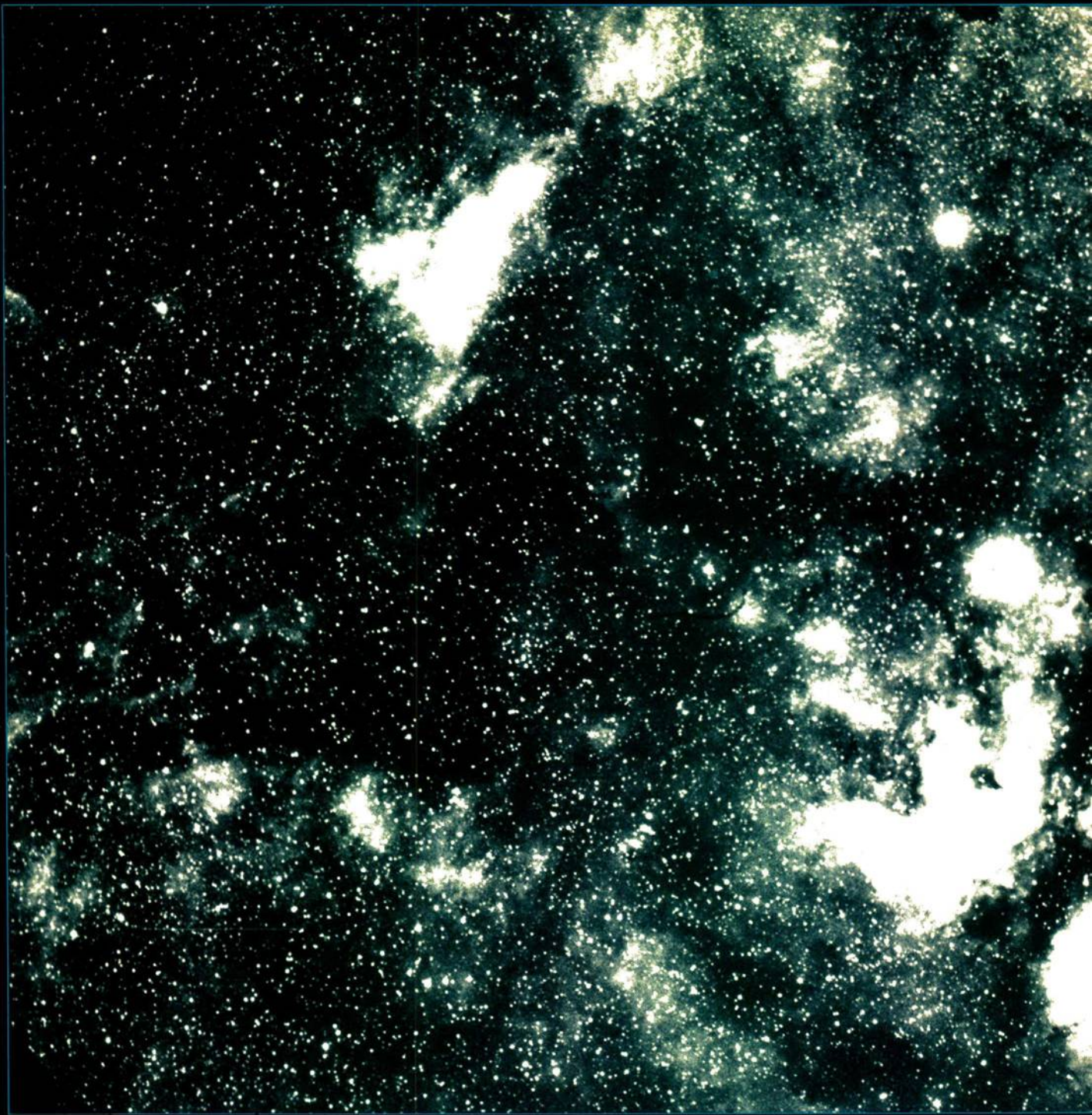
Above: The Veil Nebula, the sky's brightest supernova remnant, lies in southeastern Cygnus. Its twisted rope structure is easily captured on film. Photo by Robert Reeves; 300mm f/1.5 astrocamera, 30-minute exposure on hypersensitized TP 2415.



Top right: Coma Berenices is principally composed of a large star cluster called Melotte 111, around which numerous tiny galaxies reside. Photo (with meteor trail) by Mark Coco; 135mm f/2.8 lens, 15-minute exposure on Ektachrome 400.

Bottom right: Taurus is home of the Hyades star cluster, a nearby group of several dozen bright stars. Bright orange Aldebaran, however, is not a member. Photo by Mark Coco; 135mm f/2.8 lens, 30-minute exposure on Ektachrome 400.

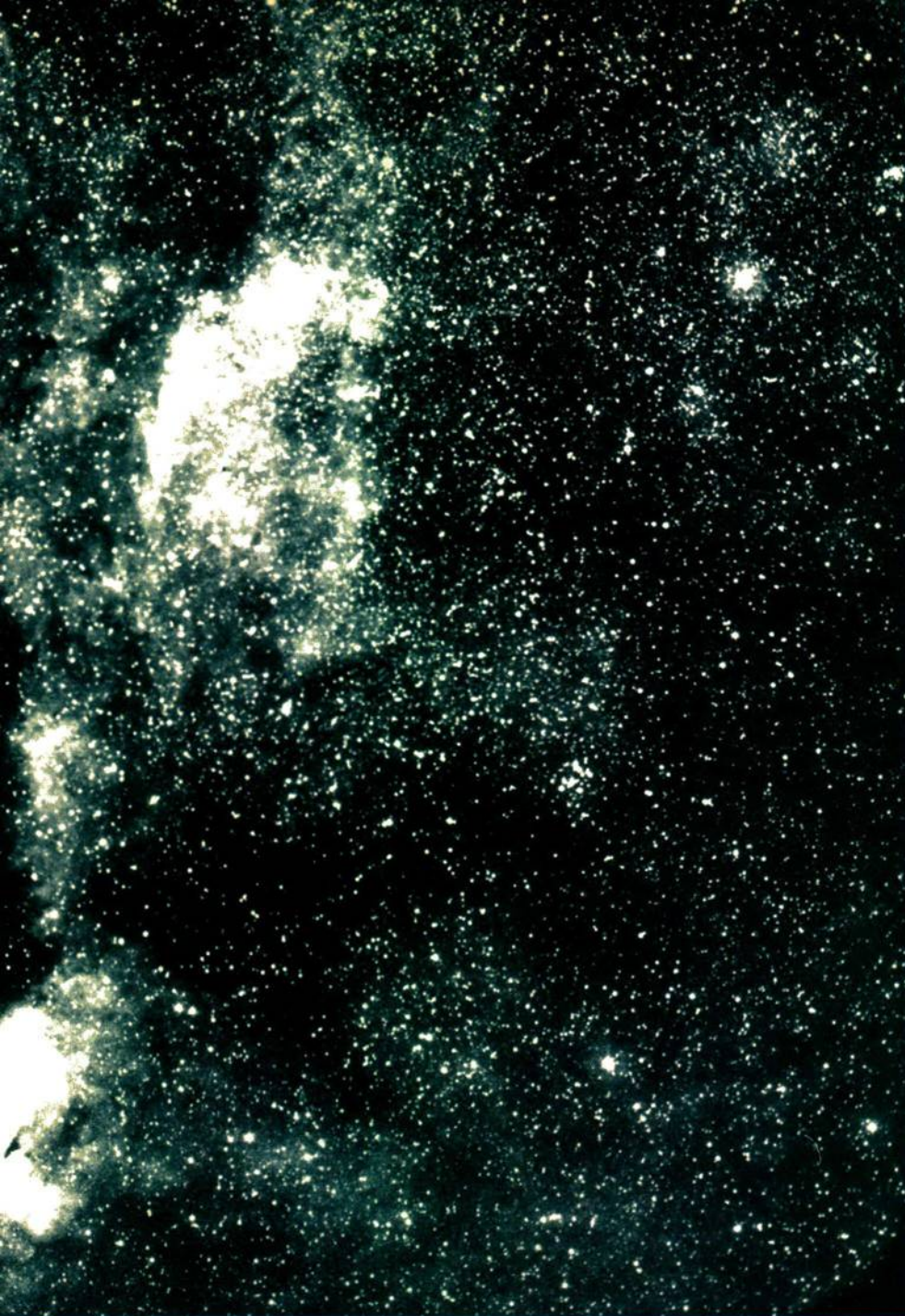




Above: The entire area encircling Gamma (γ) Cygni is filled with glowing hydrogen gas, collectively catalogued as IC 1318. Photo by Robert Reeves; 300mm f/1.5 astro-camera, 30-minute exposure on hypersensitized TP 2415.



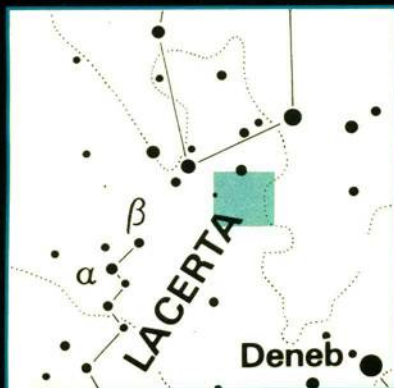
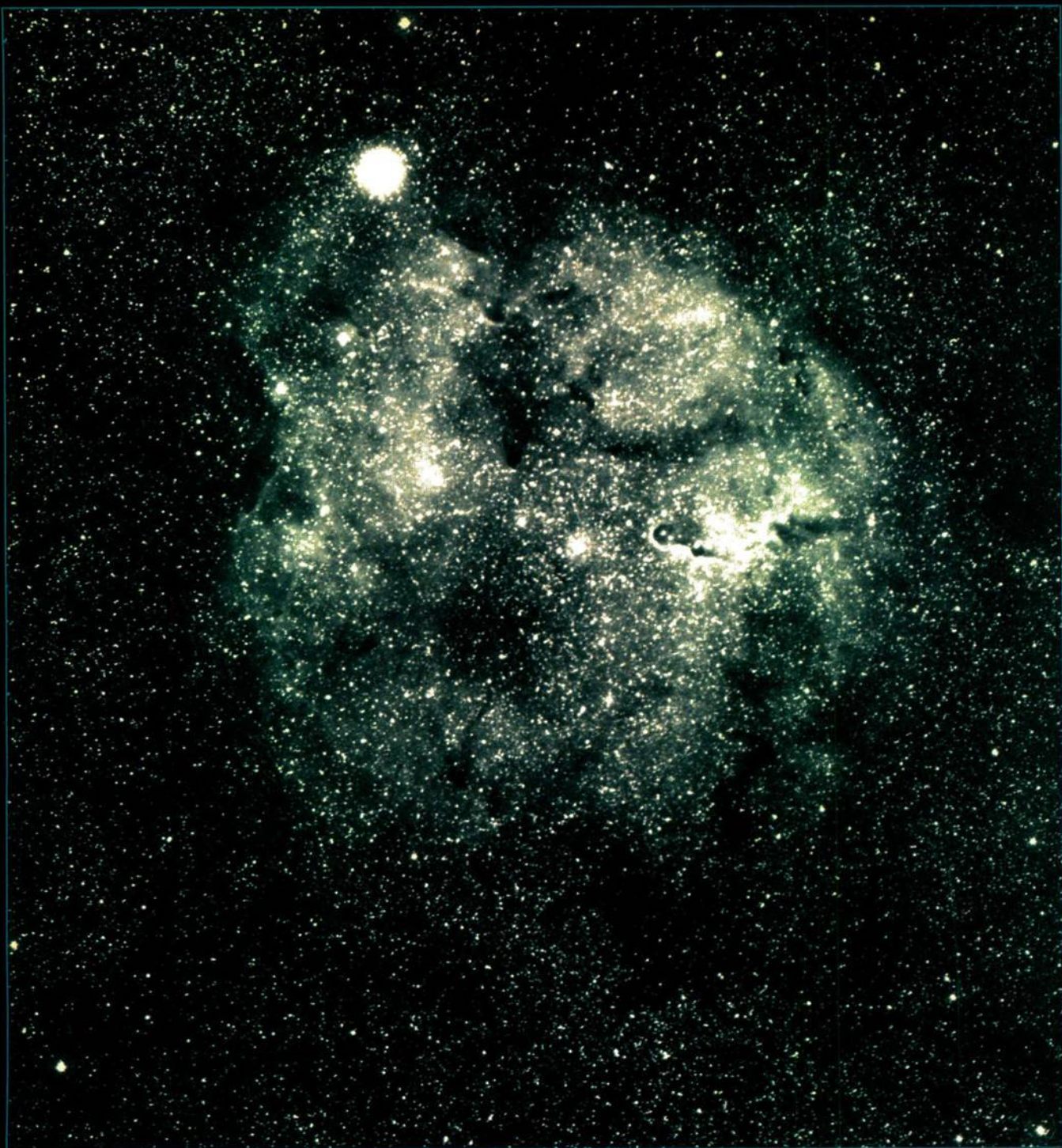
Top right: Cepheus the King holds NGC-7822, a large faint region of emission nebulosity. Photo by Robert Reeves; 300mm f/1.5 astro-camera, 30-minute exposure on hypersensitized TP 2415.



Center right: Two for the price of one: the Double Cluster in Perseus with a myriad of bright stars. Photo by Robert Reeves; 300mm f/1.5 astrocamera, 30-minute exposure on hypersensitized TP 2415.

Bottom right: The pinwheel galaxy M-33 in Triangulum offers plenty of face-on galactic detail to patient astrophotographers. Photo by Robert Reeves; 300mm f/1.5 astrocamera, 30-minute exposure on hypersensitized TP 2415.





One of the largest and brightest emission nebulae, IC 1396 in Cepheus, lies just south of the bright star Mu (μ) Cephei. Photo by Robert Reeves; 300mm f/1.5 astrocamera, 30-minute exposure on hypersensitized TP 2415.



1396. This object is very difficult to see visually, but is one of the most fascinating objects in the sky for astrophotographers. It is a circular mix of bright and faint stars, pale nebulosity, and dark truncated patches of interstellar dust. IC 1396 almost looks like someone took a cluster of stars, shook them up in a giant container, and spilled out the contents into space. The northern sky has notable star clusters, as well, in the Hyades, Pleiades, and Coma Berenices groups.

These are but a few of the many bright and intricate deep-sky objects lining the northern Milky Way. Should you still have doubts, simply scan across a map of the northern sky; once you start looking, you'll virtually never run out of targets for astrophotography — or Fantastic Tales!

Robert Reeves is an experienced astrophotographer and telescope maker. His last article was "A Portable Astrophotography Platform for Travelers" in the September 1985 issue.



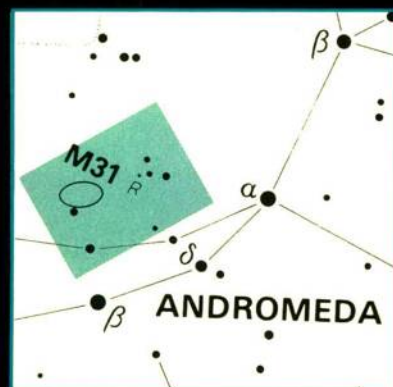
Northern Targets

- M-31, Great Galaxy in Andromeda
- M-33, Galaxy in Triangulum
- The Double Cluster in Perseus
- IC 1805 and IC 1848 in Cassiopeia
- IC 1396 in Cepheus
- The Veil Nebula in Cygnus
- Mel 111, the Coma Star Cluster
- The Hyades Cluster in Taurus
- The Pleiades Cluster in Taurus
- Region of Gamma (γ) Cygni
- NGC-7822 in Cepheus
- The North America Nebula in Cygnus



Top: The faint emission nebulae IC 1805 and IC 1848 in Cassiopeia both surround bright star clusters. Photo by Robert Reeves; 300mm f/1.5 astrocamera, 30-minute exposure on hypersensitized TP 2415.

Bottom: M-31, the Great Galaxy in Andromeda, is the Milky Way's "Sister Spiral" and everyone's favorite deep-sky object. Photo by Mark Coco; 135mm f/2.8 lens, 15-minute exposure on Ektachrome 400.



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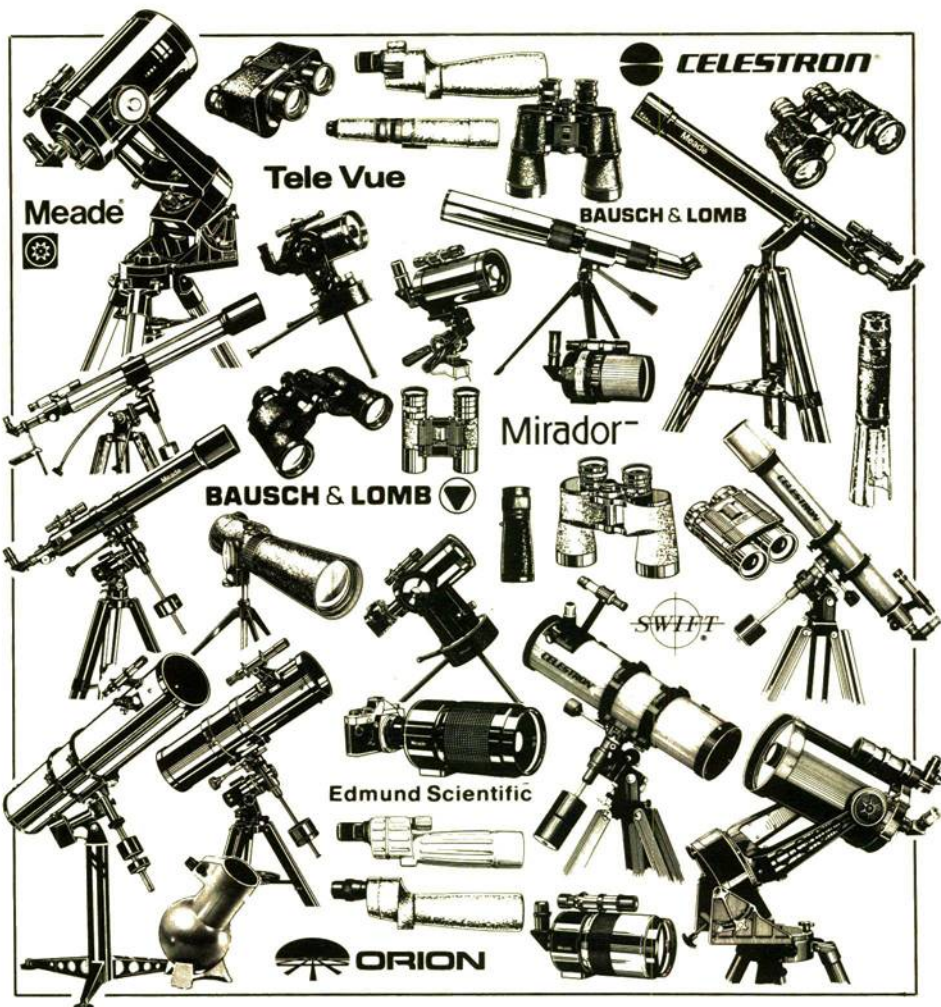
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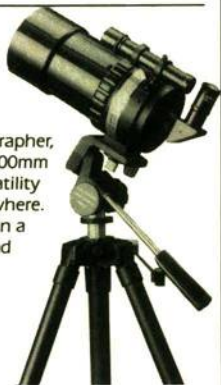
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Make Way for Halley's Comet

by Fred Schaaf

The Wanderers

As the eyes of the world turn to catch Halley's Comet at its first close approach this month, the planets seem to step to the sidelines to give the legendary visitor the limelight.

At magnitude -2 , **Jupiter** puts on November's best planet show. It is the bright "star" low in the southwest during the evening hours. This month, it will begin moving slowly eastward against the stars of Capricornus as it heads toward a meeting with Halley and the Moon in January.

Saturn won't be visible this month; it reaches conjunction with the Sun on the 23rd.

Mars is visible in the morning sky with the naked eye but it won't be very bright. Although its elongation from the Sun increases to about 50° this month, it shines at only second magnitude. During the month, it travels rapidly from the celestial equator down through western Virgo and approaches Spica toward month's end. Although it has risen by 3:30 a.m., you'll find it easiest to see about an hour and a half before sunrise.

At the dim end of its magnitude range — which is still greater than -3 — **Venus** this month moves lower in the morning twilight. Look low in the east the last hour before sunrise to see Venus pass north of Spica on the 3rd. Venus is on the far side of its orbit from us and will stay there — near the Sun from our point of view — until the spring.

Two occultations occur this month. At about 6 a.m. EST on the 11th, the Moon passes quite close to Venus; it actually occults (covers up) the planet as seen from the southern hemisphere. And another occultation on the 13th, when the Moon covers Mercury, is visible only from parts of Australia and New Zealand.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Looking east before sunrise, Nov. 10th



Mercury is in the evening sky most of November, but even reaching its greatest elongation on the 8th and inferior conjunction on the 28th — when it will be the closest planet to Earth — won't improve its visibility. This will be Mercury's poorest appearance of the year.

Only some observers in the southern hemisphere get to see the partial phases of a total eclipse of the Sun this month. The total eclipse itself — which occurs on November 12 — can be seen just in the Antarctic regions. But all the world will experience high tides on the same day of the eclipse, because the Moon will not only be New, but it will be at its closest approach of the year.

Fortunately, the Moon sets in the evening around mid-month and won't disturb our view of the **Leonid meteor shower** which should be at its peak during the predawn hours of November 17th. Look for short streaks of light — "shooting stars" — coming from the head of Leo. This famous shower is usually not very active — at peak, you'll be lucky to see 10 Leonids an hour from a country site — but about three times a century the shower puts on an absolutely stupendous show (see Skylore below). Occasionally you can see a very good display in a year when the parent comet, Tempel-Tuttle, is far away — such as now, when it is out near Uranus.

If you are out watching Halley's Comet in early November, you may see some

Gathering storm clouds provided the only filter used by Jim Baumgardt in this photo of the February 1979 partial solar eclipse. He took this shot from Los Angeles at maximum phase with a 200mm lens on Kodachrome 64 film.

bright **Taurid meteors** coming from that same part of the sky. They are derived from the second most famous of comets, Comet Encke. Some astronomers think debris from the comet may have produced the awesome Tunguska "super-bolide" which exploded over Siberia in 1908.

Seeing **Halley's Comet** will require binoculars most of this month as it passes north of the Hyades star cluster on the 11th and south of the Pleiades on the 16th. But there is a possibility of a first naked-eye sighting. Halley may brighten to magnitude 6.5, becoming visible without aid from a very dark site by month's end. There is also a chance that a flare could make the comet much brighter for a brief time.

The Starry Sky

What starry background is Comet Halley moving through this month? If you go out around 7 or 8 p.m. local time around the middle of November, you'll find Halley and its "host" constellation for most of November — **Taurus the Bull** — above the horizon to your east. The horns of Taurus point to the left as the



November's Night Sky



Last Quarter
November 5
3:07 p.m. EST



New Moon
November 12
9:20 a.m. EST



First Quarter
November 19
4:04 a.m. EST



Full Moon
November 27
7:42 a.m. EST

- 5th** Last Quarter Moon occurs at 3:07 p.m. EST. Watch for a few bright Taurid meteors coming from the same part of the sky as Halley's Comet.
- 8th** Mercury is at its greatest eastern elongation.
- 9th** Although Mars will be very dim, try to spot it tonight when it lies south of the Moon.
- 11th** Venus and the Moon lie very close together low in the dawn sky.
- 12th** A Total Eclipse will be visible only in Antarctica and the south Pacific, Atlantic, and Indian Oceans. The unusual combination of New Moon — at 9:20 a.m. EST — and the Moon's closest approach to Earth of the year — 7:32 a.m. EST: 221,749 miles — will cause unusually high tides all over the world.
- 17th** Bright Jupiter will pair up with the Moon in the evening sky. The Leonid meteors will be at their peak in the predawn sky but don't expect much of a show: you'll be lucky to see 10 an hour after midnight.
- 19th** First Quarter Moon is at 4:04 a.m. EST.
- 22nd** Saturn is in conjunction with the Sun as it passes into the morning sky.
- 25th** The Moon is farthest from Earth at 5:03 p.m. EST: 252,418 miles.
- 27th** Full Moon occurs at 7:42 a.m. EST.
- 28th** Mercury is at inferior conjunction with the Sun as it moves into the morning sky.
- 30th** Mercury is at its closest to Earth.

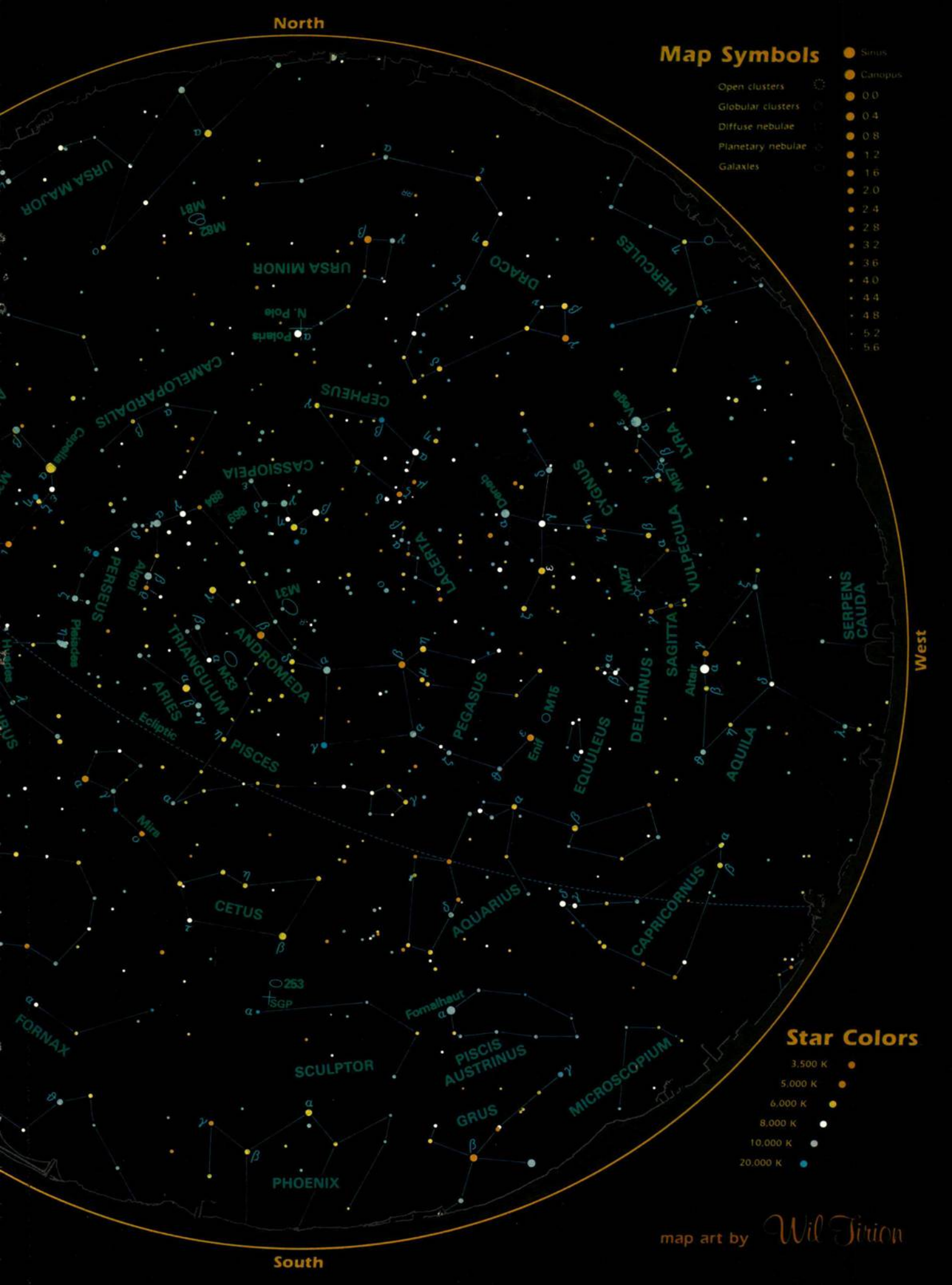
Looking south after sunset, Nov. 17th



East

The
Star Dome
shows how the
sky looks at:

9:00 p.m. on November 1st
8:00 p.m. on November 15th
7:00 p.m. on November 30th





Top: Vega rising over the Canadian Rockies. Photo by Bill Johnston; 20-second exposure on Ektachrome 400 film at f/4.5. Bottom: Kotzebue, Alaska was the site of this striking aurora borealis display, captured in January 1982 by Forrest Baldwin (50mm f/1.4 lens, 3-second exposure, Ektachrome 400 film).

constellation rises, their tips marked by two rather bright stars.

The face of Taurus is depicted by the brightest stars of the **Hyades star cluster**. And far brighter and closer, its glaring eye is a first-magnitude orange star: **Aldebaran** (Alpha [α] Tauri). It forms the end of one arm of a little "V", the rest of which is made up of the Hyades stars.

Once you've identified the "V" of the Hyades, you're ready to find the horn stars. Simply extend the arms of the "V" to the east. The first moderately bright stars you come to are Zeta (ζ) and Beta (β) Tauri, the horn points.

Beta Tauri is the brighter of the two, a second-magnitude star which helps form the pattern of another constellation, Auriga, just north of Taurus. **Zeta Tauri** is fainter than Beta, but it has a very famous neighbor less than a degree to the northwest: **M-1**, the Crab Nebula. This supernova remnant — the remains of a star explosion in the Middle Ages — is at its most stunning in photographs, but large binoculars or small telescopes show its eerie glow.

Halley's Comet passed nearest to M-1 and Zeta Tauri in the last days of October, when the Moon was bright. In November, the comet moves about 7° north of the Hyades on the 11th, as it heads for conjunction with a star cluster. Even people who know nothing at all about astronomy usually recognize this cluster: the Pleiades.

The sparkling little huddle of the **Pleiades** is more than a degree across — the Moon fits easily into the bowl of this teacup. Nevertheless, the stars are so close to each other that it is difficult to count all of them that are bright enough to see with the naked eye. The brightest Pleiad is the central one, 2.9 magnitude **Alcyone**. The Pleiades have been known since ancient times as the Seven Sisters, yet most observers on an average night — even in

the country — have trouble picking out more than six. Whether this has anything to do with the legend of the Lost Pleiad remains a mystery.

North of this cluster is the two-branched constellation **Perseus**. If you draw two southward-bending branches with **Mirfak** (Alpha Persei) in the eastern branch and the famous variable star **Algol** (Beta Persei) in the western branch, you will find that the extended eastern branch points to the Pleiades (to the south) and the Double Cluster of Perseus and Cassiopeia (to the north).

Drawing a giant equilateral triangle with the Hyades at one point and Mirfak at another will help you find, in the final point to the west, the orange second-magnitude star **Hamal** (Alpha Arietis). Hamal is the brightest star in **Aries** the Ram. The Ram is a difficult constellation to find, since it is outlined by just the small pattern of Hamal and two other stars, the much fainter **Sheratan** (Beta Arietis) and the very dim **Mesarthim** (Gamma [γ] Arietis). Comet Halley will be just a few degrees south of Mesarthim when it comes to its first close approach on the 27th of November — too bad the Moon will be Full and located between the Pleiades and the Hyades that night!

At month's end, Halley's Comet will be leaving Aries and entering Pisces the Fish. As it speeds on to its appointment with the Sun in Aquarius, don't forget to look back from time to time to further study the constellations Halley has just passed through.

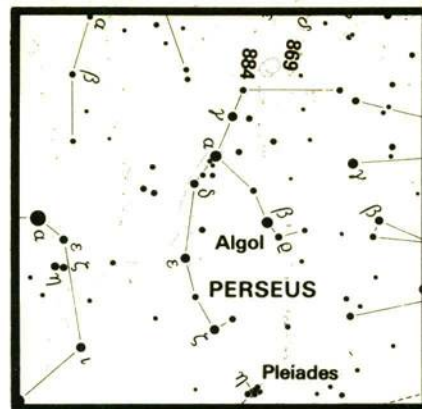
Skylore

Continuing our study of meteor and comet lore, let's take a look at the two meteor showers associated with Halley's Comet, and the greatest meteor storms known in history: those of Comet Tempel-Tuttle and the Leonids.

There is, of course, too much to say about the Eta Aquarids and Orionids, let alone their parent, for our short space here. But the question of whether Halley's passage might produce greatly enhanced showers is an interesting one.

Great Orionid and Eta Aquarid storms are possible when a very dramatic thing happens to Halley's orbit: its nodes cross our own orbit. The ascending and descending nodes of the comet are the places where it passes up and down, respectively, through the plane of Earth's orbit. The last time one of them was right at the orbit of Earth was after the Halley return of 530 A.D. — when the descending node, the one associated with the Eta Aquarids, passed inward across our orbit. Did anything happen around that time? Yes! Great displays of Eta Aquarids were recorded in 443, 466, and in 530 A.D. They were described by the Chinese as true meteor storms: "their numbers past counting," "numbered in thousands."

Since Halley's orbit for this apparition



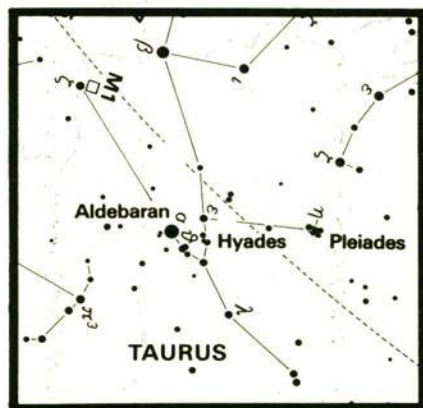
won't come closer than about 3 to 4 million miles from the Earth's, we aren't likely to see any tremendous Eta Aquarid storms (the meteor shower that occurs around May 4th), and we are even less likely to see active Orionids (the October shower).

If you want meteor storms, your best bet — in dependability, number of occurrences, and greatest number of meteors — is Comet Tempel-Tuttle and the Leonids.

A close Earth passage of Comet Tempel-Tuttle by the Earth has been noted as far back as 1366 — the only pre-telescopic case of a short-period comet (other than Halley) having a past return identified. This gives you some idea of how stable the comet's 33-year orbit is. Yet looking back in the historical records, we find great Leonid storms didn't always occur in the year after the comet's passage. Some great displays were seen when the comet was out near aphelion, its farthest from the Sun. Among the great displays of the Middle Ages was the one in 902, which became known in Arabic culture as the "Year of the Stars," because so many were seen streaking across the heavens.

The 1799 Leonid storm was seen throughout most of North America and South America — even by Moravian missionaries in Greenland. The great Alexander von Humboldt, who was then in South America, wrote "Thousands of bolides and shooting stars succeeded each other during 4 hours . . . there was not a space in the firmament equal in extent to 3 diameters of the Moon that was not filled every instant with bolides and falling stars."

The storm of 1833 may have been one of the the greatest Leonid storms. It was the night "the stars fell on Alabama" and people in Boston were awakened from sleep by the flashes of meteors. As many as 35,000 meteors per hour were reported. But in 1966 the swarm was back, with the greatest meteor storm known in history for observers in the southwest United States. At Kitt Peak Observatory there was a rate of 150,000 per hour for about 20 minutes and brief bursts as great as 140 meteors per second — over 500,000 meteors per hour!



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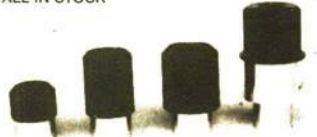


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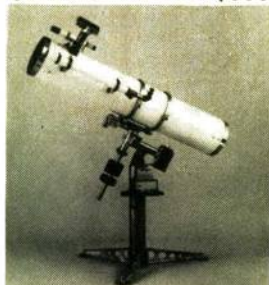
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Photograph of Halley in 1910, courtesy of Lick Observatory.

Your First Shot at Halley's Comet

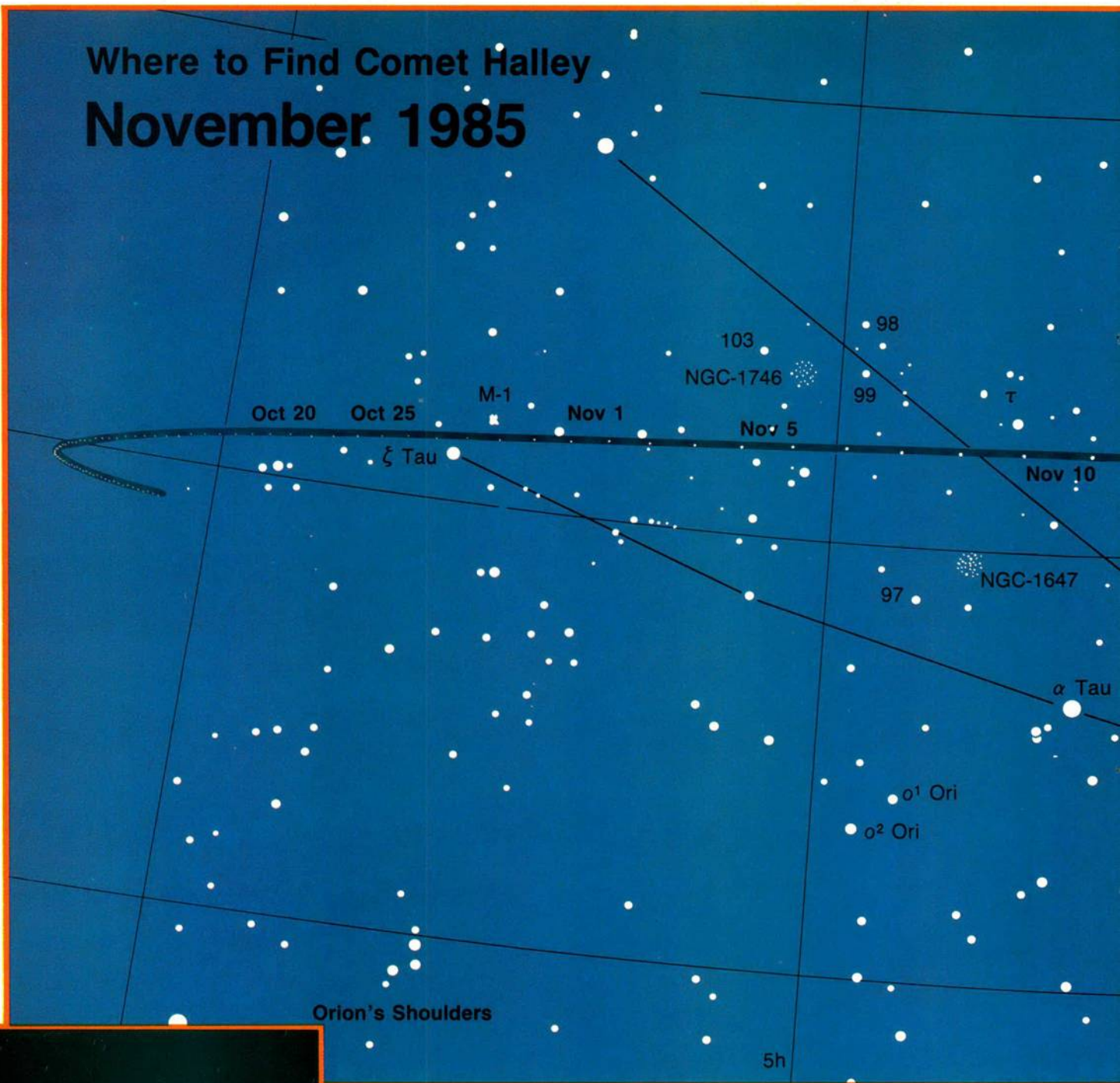
Gazer's
Gazette



In November and
December, you should have
no difficulty finding Comet
Halley as it traverses Taurus
and Pisces.

Where to Find Comet Halley

November 1985



Get ready to take your first shot at Halley's Comet. In November, as it swings closer in toward the Sun and develops a larger coma, Comet Halley will finally become bright enough to observe with modest backyard telescopes. True, a small handful of amateur observers spotted the faint smudge as early as mid-August, when the comet shone at about 15th magnitude. But during November Halley will brighten to 10th magnitude, enabling owners of binoculars or small telescopes to follow it from any reasonably dark sky site. And by the end of 1985, Halley's Comet will shine at seventh magnitude — teetering on the verge of naked-eye visibility.

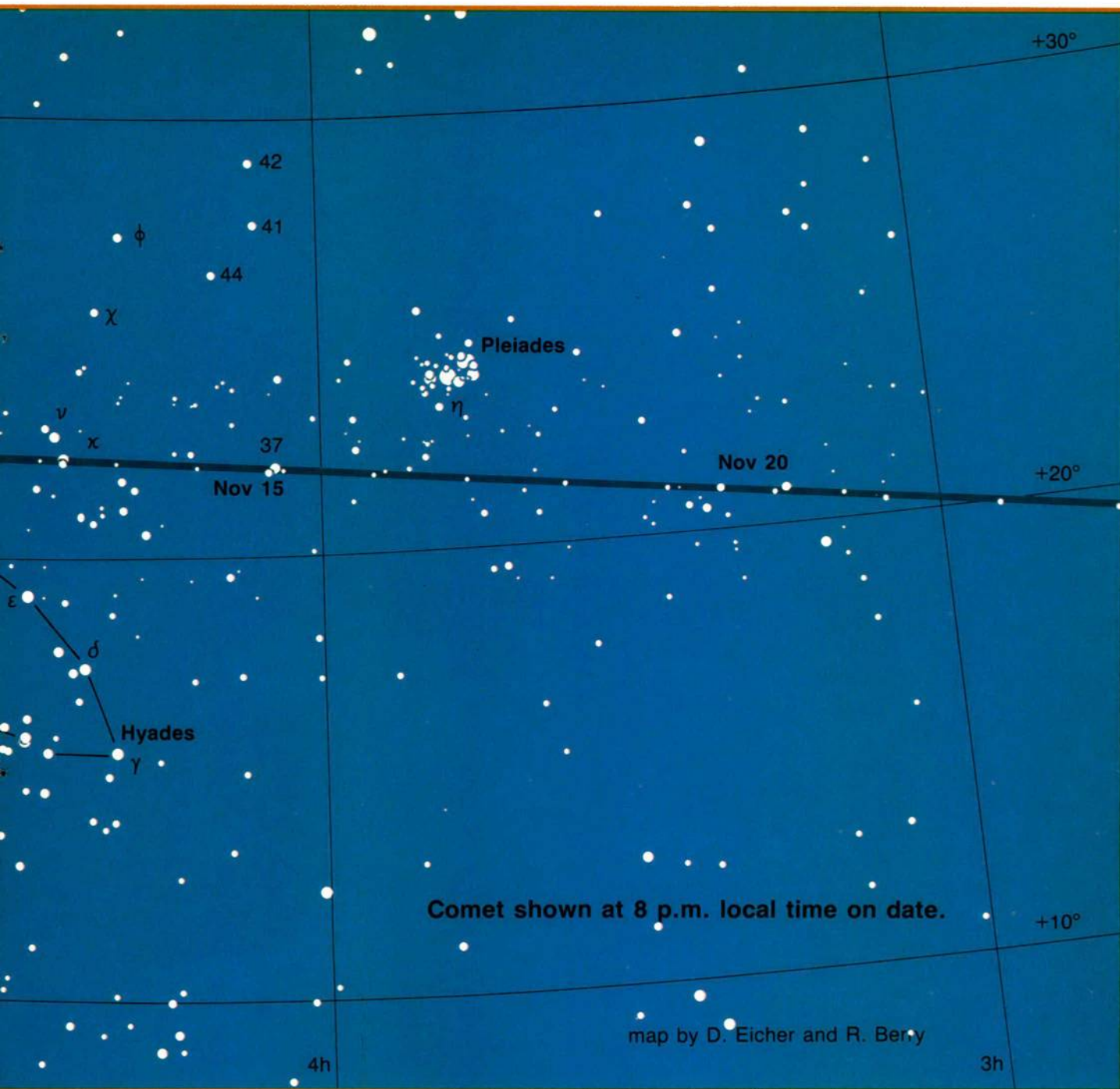
During both November and December, Halley will be visible in the evening sky

essentially as soon as astronomical twilight ends. Aside from unfavorable weather, the sole restriction on observing Halley during this period is the Moon, which interrupts viewing by filling the sky with its glare. For this reason, there are two distinct "windows" — one three-week period each in November and December.

November: Moving Through Taurus

Early in November, Halley's Comet lies northeast of the Hyades star cluster in Taurus, slowly moving almost due west. As the month goes on, Halley will gradually accelerate and pass between the Hyades and the sparkling Pleiades cluster, affording an excellent opportunity for astrophotographers.

Before running outside to observe, do



a little preparation. Get your telescope ready, check to see that you have the appropriate eyepieces and filters, make sure your finderscope's aligned, and get a reliable red-filtered flashlight. (Use several layers of red cellophane, or brown paper-bag paper, over the flashlight's lens; this will allow you to read star charts without ruining your night vision.) While still inside, carefully study the star backgrounds on the two accompanying finder maps. These will get you "zeroed in" on Halley's Comet after you locate the right section of sky.

November's observing window runs from the 1st until the 17th or 18th, when the Moon reappears in the evening sky. At the beginning of the month, Halley will

shine at about magnitude 10.8; on the 3rd it lies just south of the fifth-magnitude star 109 Tauri, appearing in the same low-power field of view. On the 6th and 7th, Halley will move about a degree south of the bright star cluster NGC-1746. By this time, it will be 10th magnitude and probably look like a typical Virgo cluster galaxy. Although its size is also difficult to predict, Halley will probably appear fairly small and condensed at this point, though it may show signs of a tail.

Toward the middle of November, the comet picks up speed and moves directly north of the sprawling Hyades cluster. The Hyades is so large and bright that it is the most logical starting point for finding the comet during November. Start by

centering Aldebaran — the brightest star in the area — in your finderscope, then move about a degree north. You're now on the east/west "line" of Halley's path and need only check the map to see how much to move east or west in order to find the celestial visitor.

On the 10th, Halley will shine at magnitude 9.3 — easily bright enough to see in binoculars — and lie less than a degree south of Tau (τ) Tauri. At this point, it will lie some 76 million miles from us and 165 million miles from the Sun. By the 12th, Halley will move near the group of bright stars formed by Nu (ν), Kappa (κ), 67, and 72 Tauri; the following two nights it moves just north of a triangle of stars that includes 51, 53, and 56 Tauri.

Where to Find Comet Halley December 1985

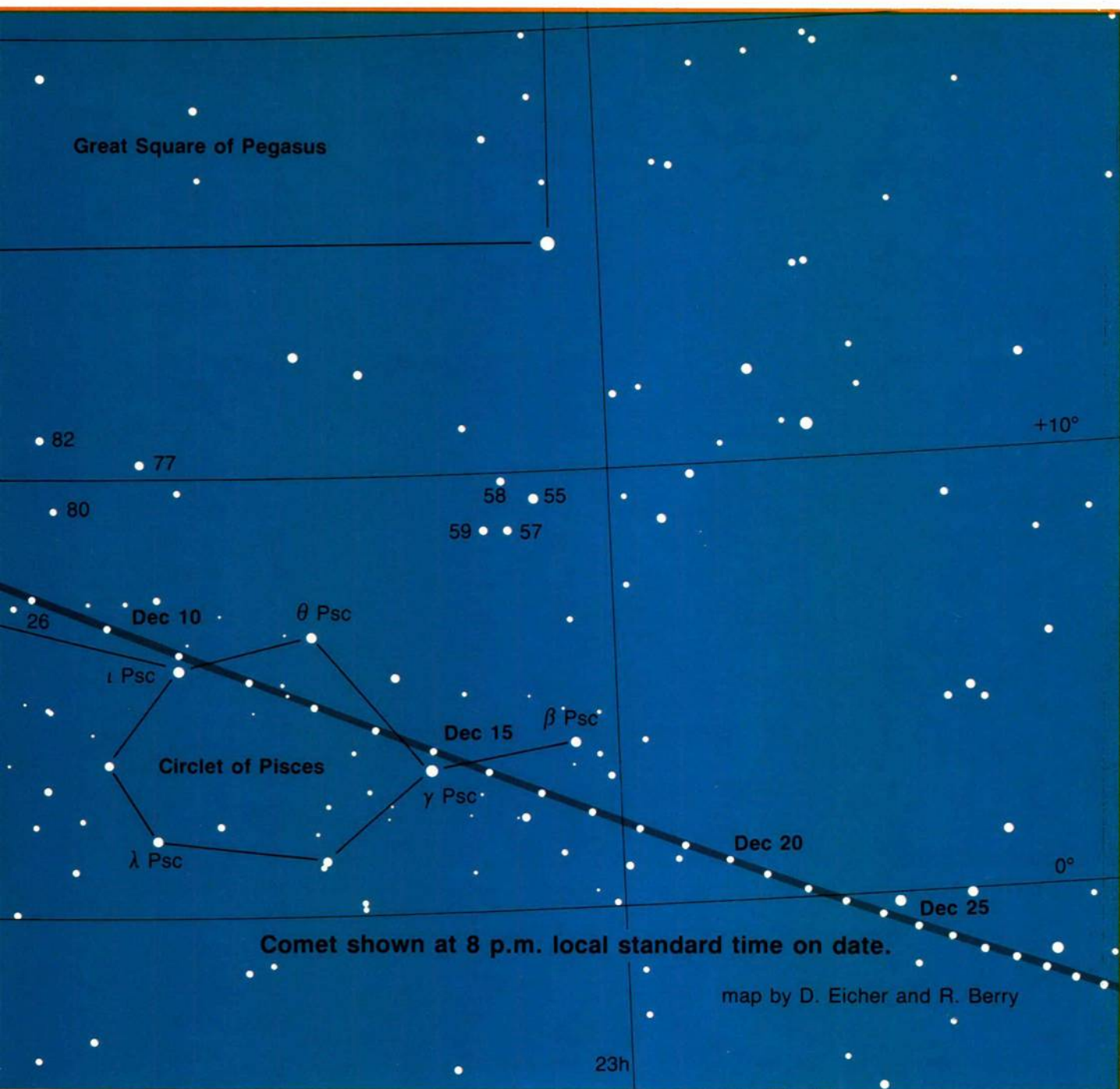


And on the 15th, Comet Halley will lie right in front of the bright pair of stars 37 and 39 Tauri. At this point it will be brighter than ninth magnitude and may well have a nicely-developed, albeit short, tail. On November 17th, Halley will be a degree-and-a-half due south of the Pleiades cluster. Shortly thereafter, just as Halley moves out of Taurus and into Aries, the Moon moves back into the evening sky and forestalls good observing prospects until December.

December: On Toward Aquarius

As December begins, Halley's Comet continues brightening and moving west. It also starts to move south, dipping below the Great Square of Pegasus, through the Circlet of Pisces, and toward Aquarius.

On the first of December, the Moon is in the morning sky and well out of the way of the comet — Halley then lies midway between two sixth magnitude stars located six degrees north of Epsilon (ε) Piscium. Shining at magnitude 7.6 and likely sporting a diminutive tail, Halley will be bright enough to easily spot in finderscopes and binoculars. It is now 59 million miles from Earth and 130 million from the Sun. On the night of the 3rd, Halley passes 58 Piscium, a magnitude 5.5 star. On the 6th, at magnitude 7.4, it moves by a group of three bright stars — 35, 36, and 41 Piscium. On the 8th, Halley glides by the pair 31 and 32 Piscium (magnitude 6.3 and 5.6 stars, respectively), and lies two degrees north



of the bright star Omega (ω) Piscium.

When you observe Halley during December, you won't have as many bright, recognizable patterns of stars to hop from as you did back in Taurus' rich Milky Way in November. This is compensated for by the fact that Halley will be brighter now — enough so that spotting it shouldn't be difficult — even in the barren starfields of Pisces.

Still gradually brightening and moving southwest, Halley's Comet will move by Iota (ι) Piscium and into the Circlet on December 11th and 12th. Probably glowing at magnitude 7.2 and showing a tail, the comet will be most easily spotted by using a low-power eyepiece, or by scanning the area with binoculars before

observing with a telescope. On the 15th, Halley will pass out of the Circlet and just north of the attractive double star Gamma (γ) Piscium, heading for Aquarius. On the 17th, Halley will shine at magnitude 7.0 — possibly just visible to the naked eye as a tiny fuzzy patch under a dark sky — and will have moved slightly farther away from Earth in space. By the 19th, the First Quarter Moon will brightly overwhelm the comet's subtle detail.

— David J. Eicher

At press time, Halley's Comet is a 14th magnitude object in Orion; it appears some 30" across and resembles one of

numerous typical little NGC galaxies. What will its exact appearance be as it brightens within the range of backyard telescopes? How soon will it develop a recognizable tail? Will the anticipation of seeing this famous celestial object pay off in terms of satisfying views during the next few months?

Although amateur astronomers have now observed Halley's Comet and professionals are busily competing for telescope time to analyze it, no one knows exactly how this apparition will go. Only one thing is certain: the observing windows in November and December will give good indications for the spring, when Halley's Comet will brighten to peak visibility.

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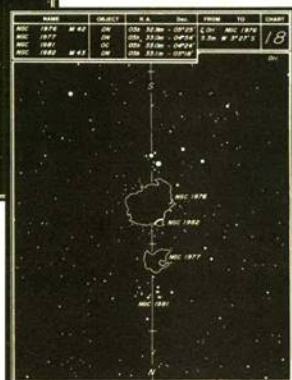
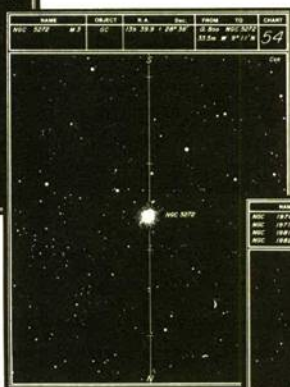
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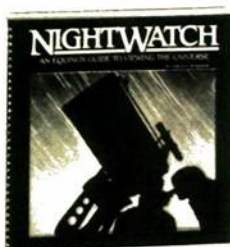
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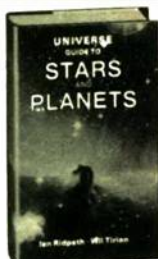
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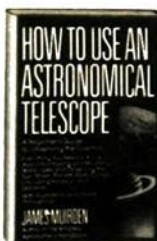
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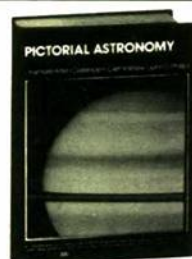
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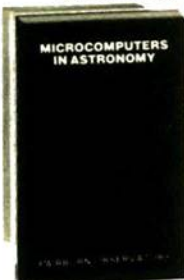
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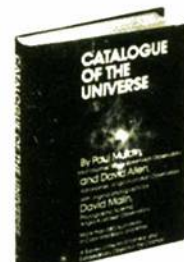


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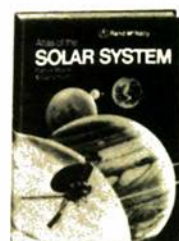
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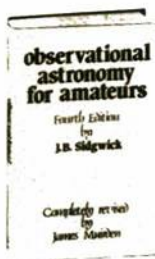
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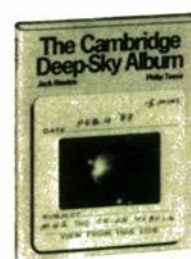
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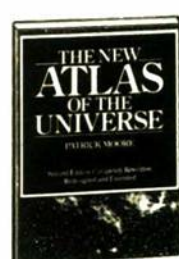
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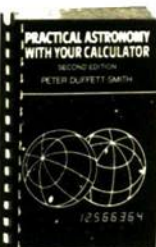
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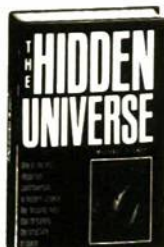
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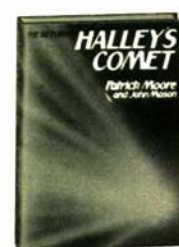
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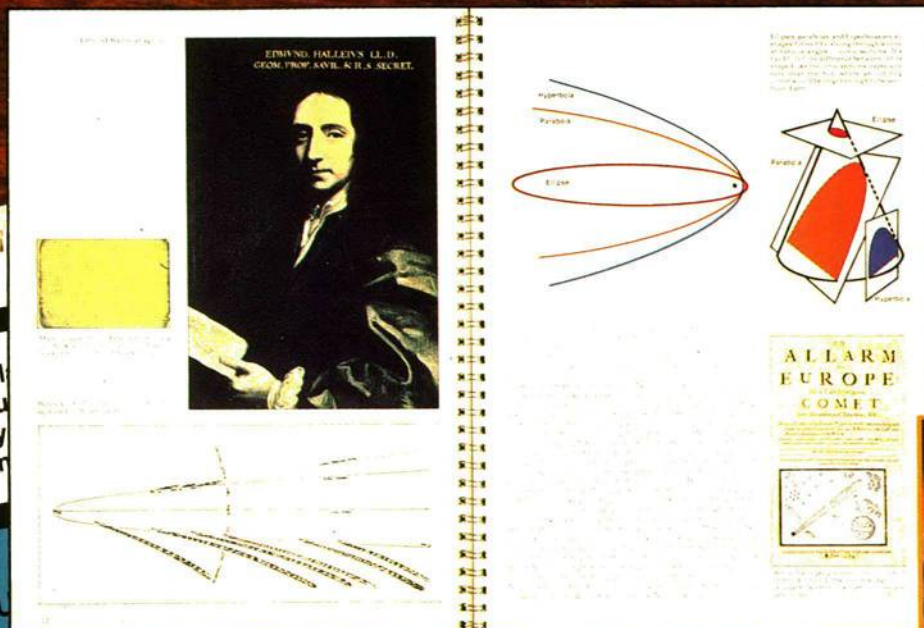
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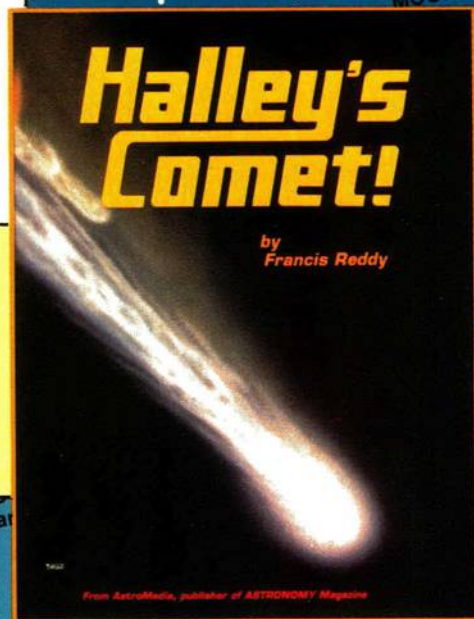
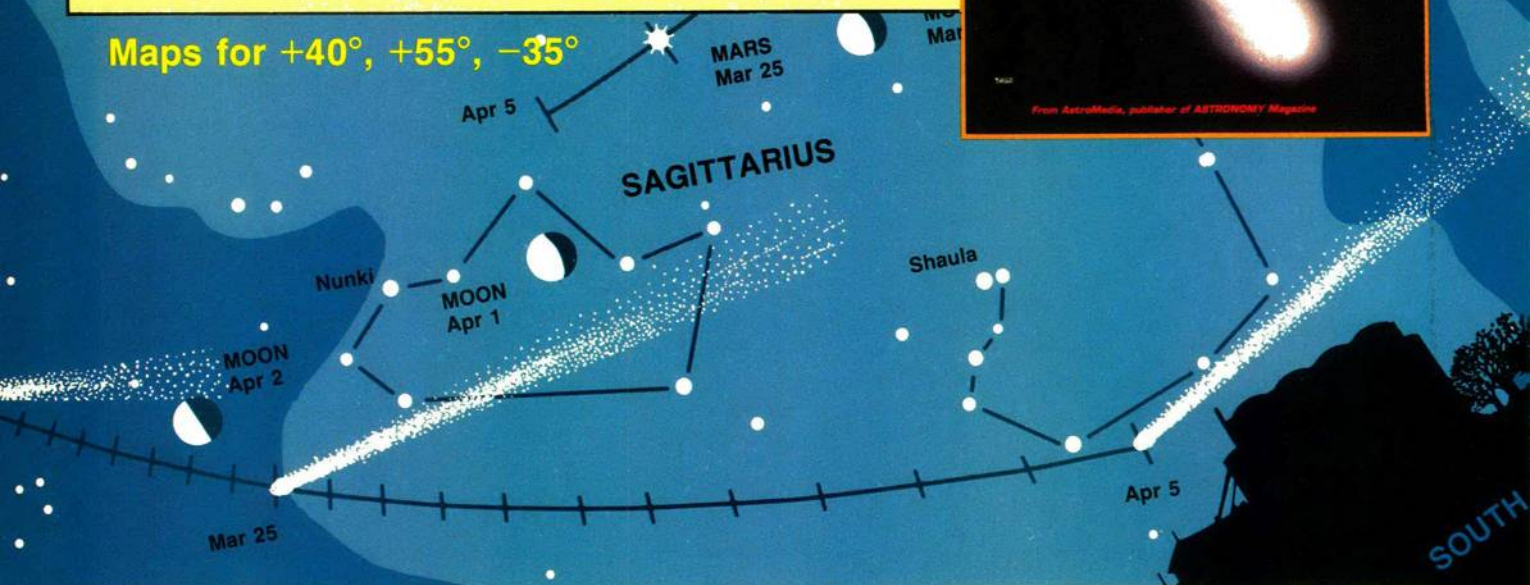
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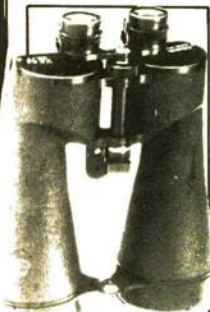
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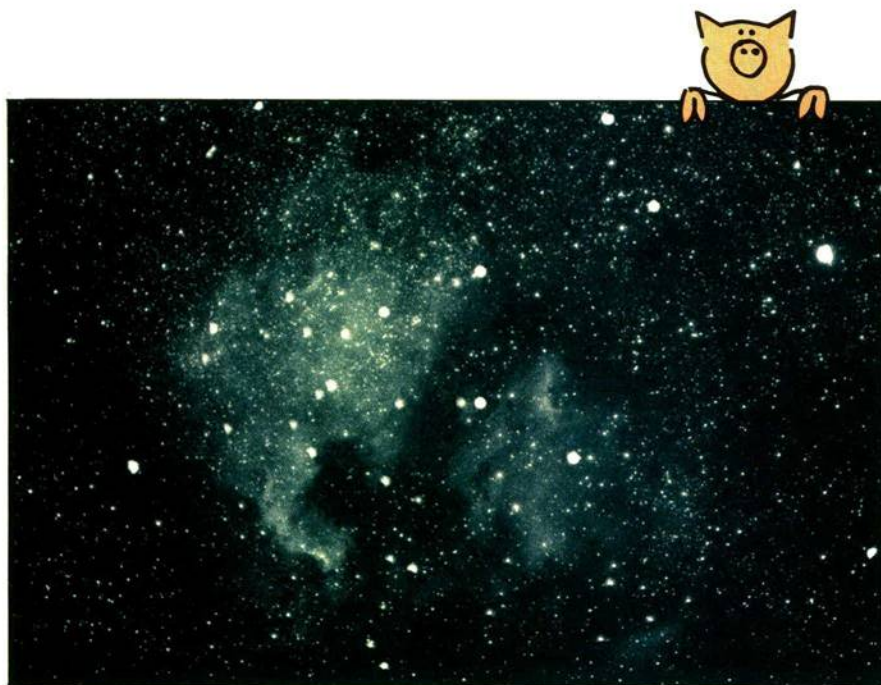
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How to Get Started in Piggyback Astrophotography

by
Mark Coco and Stephen Edberg

Photography in Astronomy



A piggybacked 15-minute exposure using 103a-E film and a 300mm f/2.5 lens, this photo shows the North America and Pelican Nebulae. Photo by Robert E. Flory.

Sooner or later, nearly everyone who owns a telescope dabbles in astrophotography. Their first photographic subjects are usually the Moon and planets. But once budding sky photographers get a few good exposures of Saturn near Venus or the Moon and Mars, their thirst for new subjects increases. What's left after the solar system? So-called deep-sky objects — clusters, nebulae, and galaxies. What's the easiest and most practical way to start photographing deep-sky objects? Piggybacking's the answer — using an equatorially-mounted telescope as a platform for a camera which "piggybacks" on top. The camera photographs through a wide-angle, normal or telephoto lens while the telescope serves as a guiding platform to ensure that the star images are pinpoint sharp over long time exposures.

Why Piggyback?

Piggybacking offers several advantages over taking pictures through the telescope. Most telescopes have such long focal lengths that they cover a very small amount of sky. This means that guiding the telescope to counter Earth's rotation

— and getting stars to appear as points rather than blurs in the photo — is a difficult chore. Piggyback photography overcomes this difficulty by using the long focus telescope as a guidescope while the picture is taken with the shorter-focus camera lens — which is more forgiving of guiding errors.

A typical piggyback shot can be made with a wide-field (28mm), standard (50mm), or telephoto (80mm to 250mm) lens. Let's say you have a 6-inch f/8 reflector and you're piggybacking a 135mm lens, which covers $10^\circ \times 15^\circ$ of sky. If you use a 12mm illuminated reticle eyepiece in the telescope, you'll have a guiding magnification of about 100x and a field of view in the eyepiece of about $15'$. Because the field covered by the camera is so large, all you need do is keep a star in the center of the guidescope's field of view and you'll have nice looking star images on film.

Aside from relative ease of guiding, piggybacking cuts down on the time involved for astrophotography. Most telescopes work at effective focal ratios —

photographic "speeds" — of f/5 or less. (Most of the popular Schmidt-Cassegrains are f/10 instruments.) But piggybacking allows you to choose a fast lens — one in the f/1.4 to f/3.5 range — enabling you to keep exposure times short. This has obvious benefits, not the least of which is keeping the amount of guiding to a bare minimum.

What Equipment Do I Need?

Piggyback astrophotography's greatest asset is that it doesn't require fancy equipment. Of course, you'll need a telescope with a clock drive, but it need not be large or elaborate. In addition, slow motion controls on both the right ascension and declination axes are helpful. Although convenient, you don't necessarily need an illuminated reticle eyepiece: you can use a regular eyepiece and defocus a star for guiding.

You will need a camera with a setting that can take time exposures. (35mm cameras are the most popular format, but any camera with time exposure capability will work.)

How do you attach the camera to the telescope? You can either buy an adapter (some of the large telescope manufacturers sell metal bracket adapters) or you can build one using parts from a hardware or photography store. You can either clamp a piece of wood or metal on the telescope using a hose clamp, elastic straps, "bungee" cords, or drill your telescope's tube so that it accepts a screw and "ball head," available from photographic shops. The ball head is convenient since it enables you to point the camera in any direction. Mounting the piggyback adapter as close to the front end of the telescope as possible prevents the front of the telescope from appearing in your photos, an annoying and prevalent problem

(especially with wide-angle lenses). However, mounting the adapter close to the front can also throw the telescope way off balance. Using a ball head, you can mount the camera back near the tube assembly's center of gravity and still be able to point your camera away from the tube. The ball head can also be mounted on a commercially-made piggyback adapter.

You can take piggyback photos with any type of lens, but it's best to begin with a normal 50mm or shorter focal length. Many objects make good wide-field targets such as the obscuring dust clouds of the Milky Way, the nebulosities in Orion, and the Virgo cluster of galaxies. After doing some wide-field photography, experiment with telephoto lenses, which require more careful guiding.

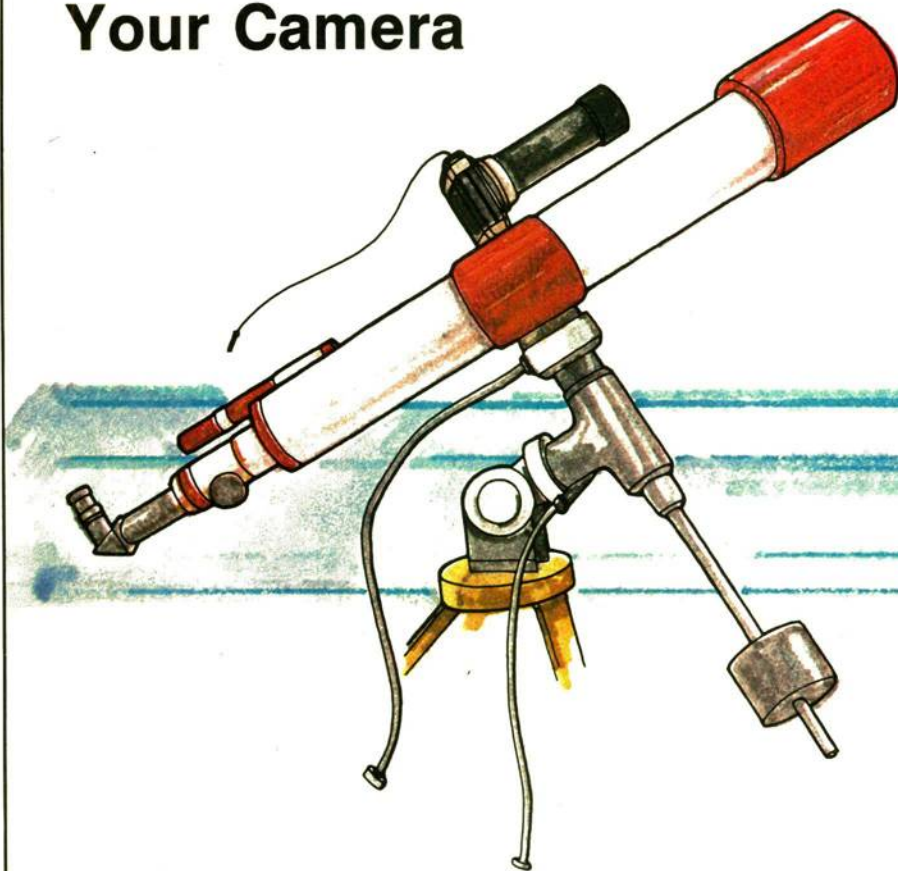
What About Films?

Film selection is an important facet of piggyback astrophotography. Fast films are desirable since they keep exposure times to a minimum. However, the super-fast films are pretty grainy and do not always record nebulosity well, and so you'll have to find a workable balance. For example, Kodak's VR 1000 is very grainy, and records nebulosity well, while Ektachrome P800/1600, though less grainy, does not record nebulosity as well. Of the fast films on the market, the 3M 1000 film is possibly the best. It records both stars and nebulosity well, and isn't too grainy. Some of the more popular fine-grained fast films are Ektachrome 400 and Fujichrome 400. In general, slides are best: they're easier to work with and record nebulosity better than prints. You can have the film processed and returned uncut and unmounted, then cut and mount it yourself. Make sure to include a couple

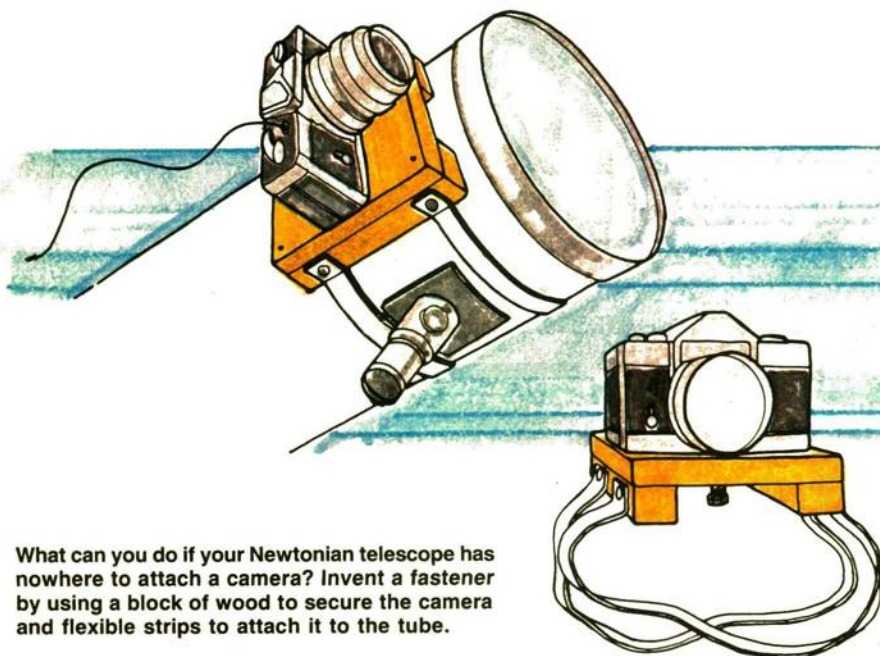
Piggybacking wide-angle lenses results in sweeping images of the sky. This photo, made with a 28mm f/2.8 lens piggybacked on a 14-inch SCT, shows the winter Milky Way. Photo by David Healy.



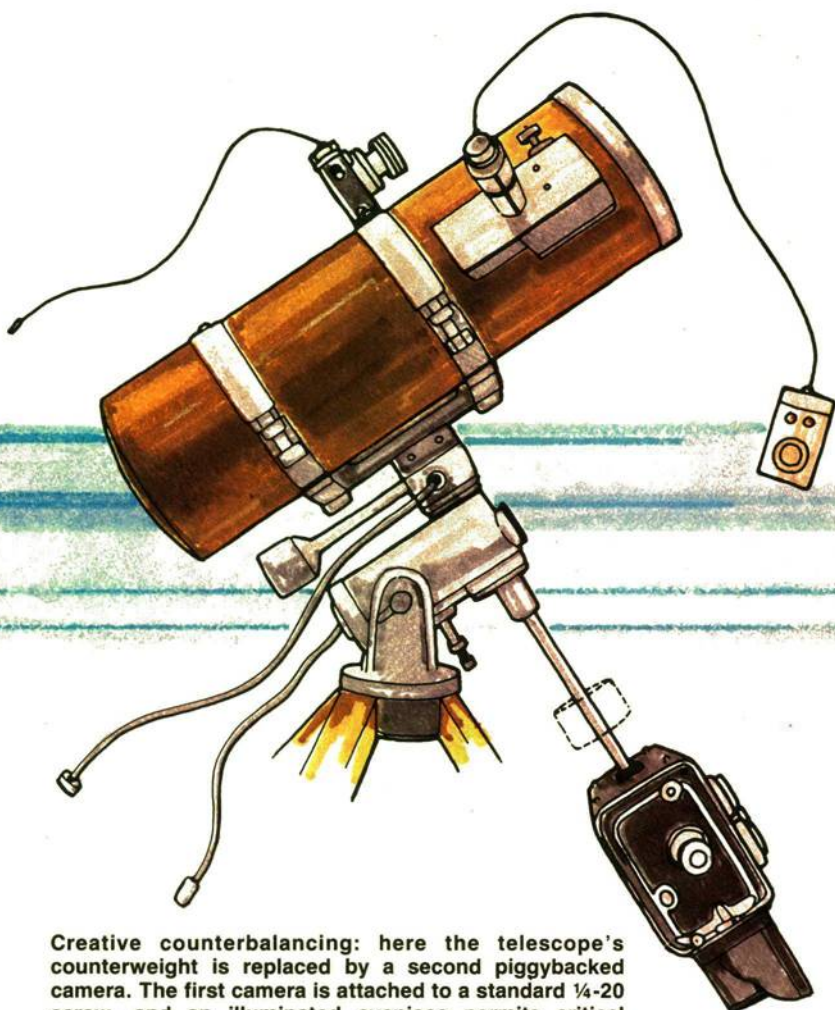
Piggybacking Your Camera



You don't need electricity to piggyback a camera: a refractor with manual slow-motion controls does a fine job. If you mount a camera on the polar axis, choose a lens which doesn't record the telescope's tube in part of the frame!



What can you do if your Newtonian telescope has nowhere to attach a camera? Invent a fastener by using a block of wood to secure the camera and flexible strips to attach it to the tube.



Creative counterbalancing: here the telescope's counterweight is replaced by a second piggybacked camera. The first camera is attached to a standard 1/4-20 screw, and an illuminated eyepiece permits critical guiding.



Most commercial SCTs have threaded holes for specially-made metal camera brackets that are available from telescope manufacturers.

Illustrations by Pat LaBrecque



Piggybacked lenses needn't be especially fast: a 135mm f/4 lens opened for 31 minutes recorded the Andromeda Galaxy on 103a-F film. The camera rode atop an 8-inch SCT. Photo by Martin C. Germano.

of "people shots" at the beginning of the roll to show where the frames begin.

For black and white photography, Tri-X film is excellent. It's fast (ISO 400), moderately grainy, and records nebulae well. A much slower, finer-grained film is 2415 Technical Pan. This film has an ISO rating of about 100. It is slow, but offers ultra-high resolution.

How Long to Expose?

Exposure times generally depend on the film you're using and the f/ratio of the lens. Fast film records more detail in a shorter exposure than slower film, but every film reaches its limit when the sky background fogs up. Slower films can be exposed longer, but even they have an upper limit. If you're using ISO 1000 films with a 50mm f/1.8 lens, the exposures should range between 5 and 20 minutes. Try to make progressive exposures of 30 seconds, 1 minute, 2 minutes, 5 minutes, 10 minutes, etc., to find out which give the best results. For the ISO 400 films, start at 15 minutes with a 50mm f/1.8 lens and do not exceed 30 minutes. Remember, slower films require longer exposure times.

Piggyback photography is a quick, easy and inexpensive way to get started in serious astrophotography. All you need is a telescope, equatorial mount and clock drive, camera, and film. Once you get started and figure out what exposures work for different situations, there's a whole sky full of starfields to photograph.

Mark Coco is an avid astrophotographer. Stephen Edberg is the coordinator of Amateur Observations for the International Halley Watch. He is co-author of "Observe: Comets," which was recently published by the Astronomical League.



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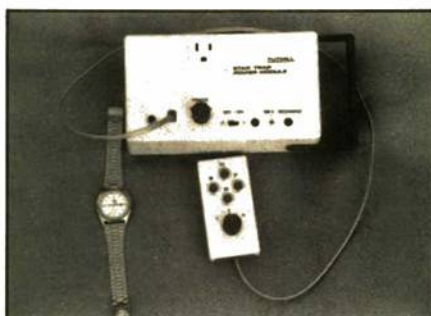
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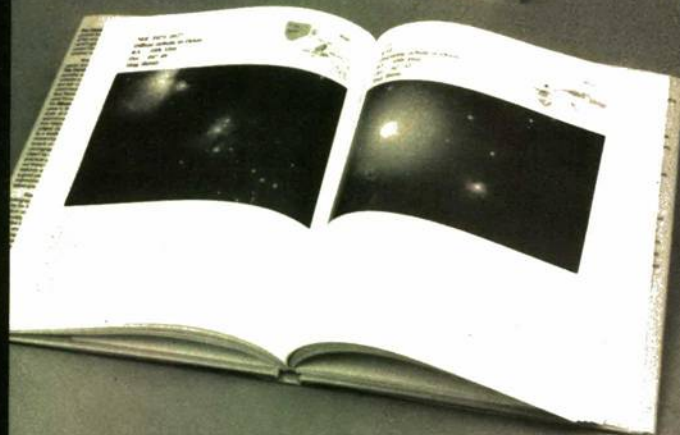
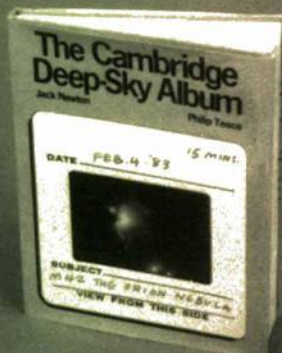
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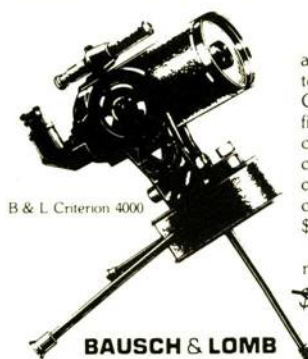
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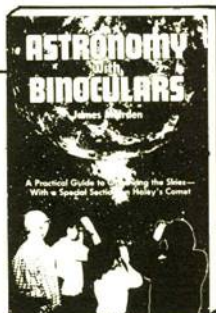
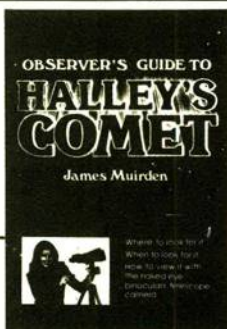
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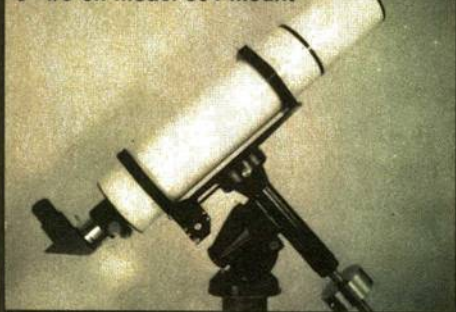
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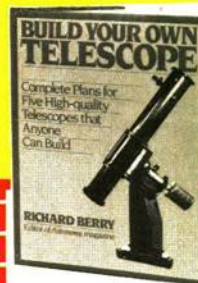
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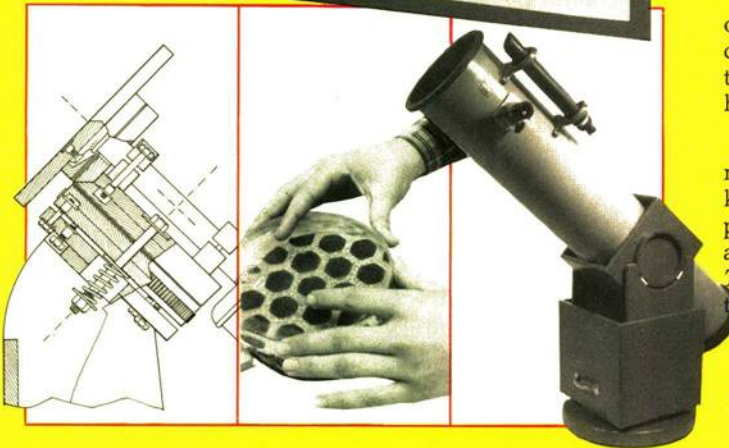
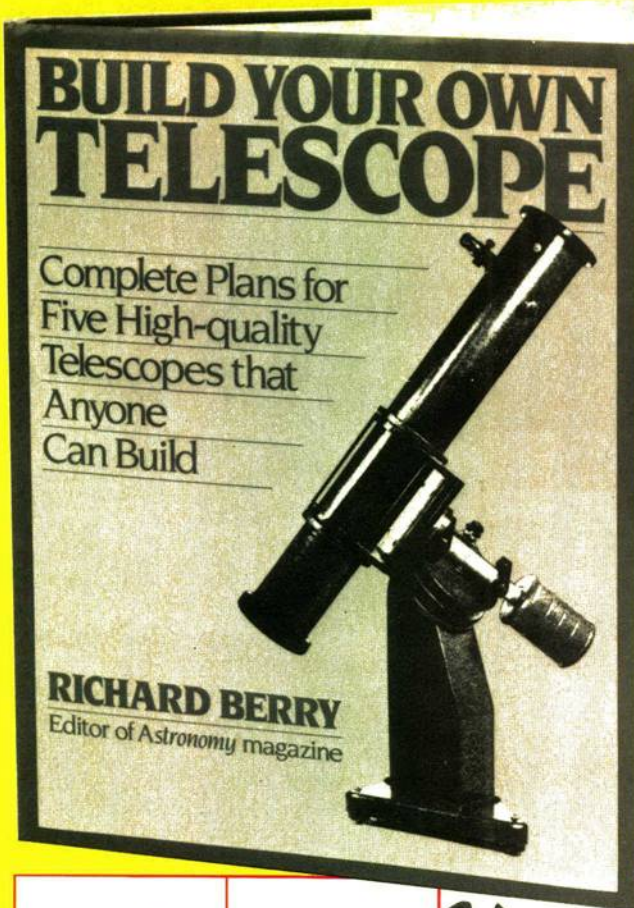
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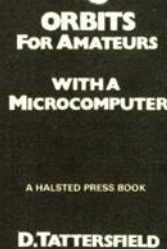
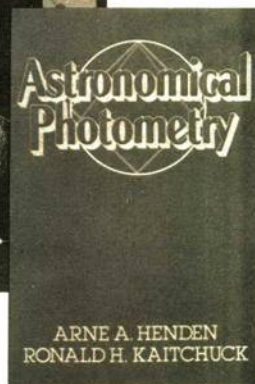
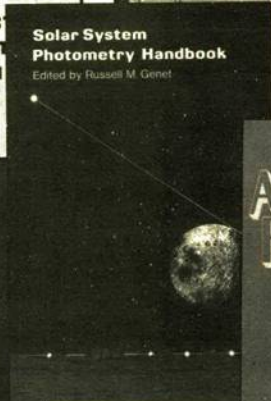
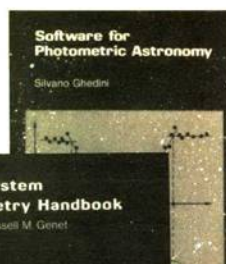
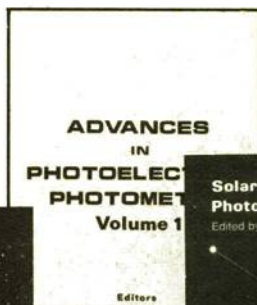
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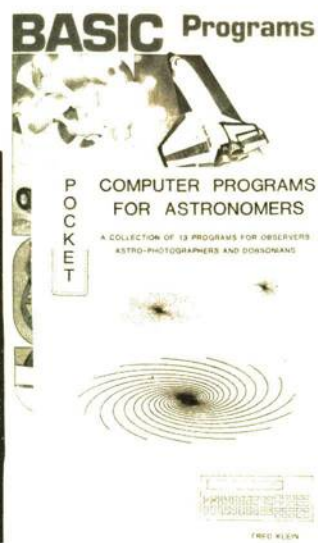
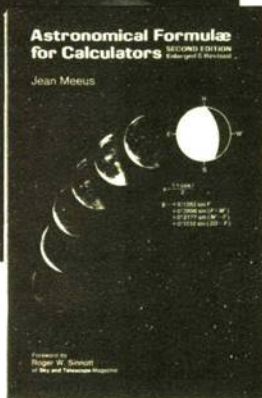
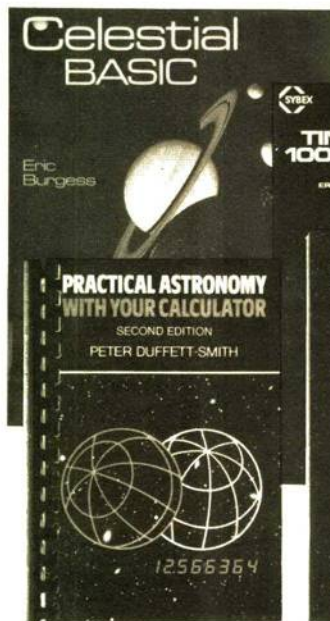
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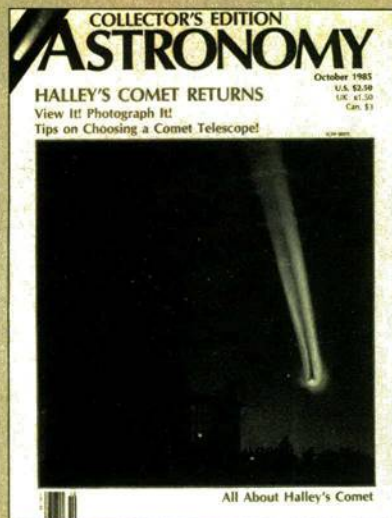
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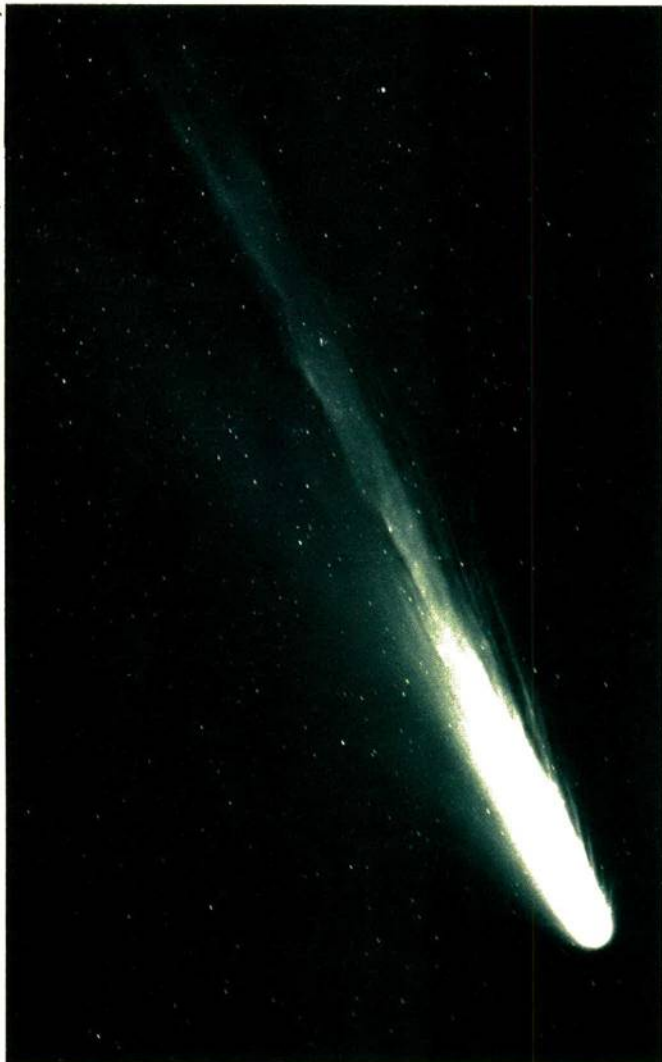
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Comet West

Can Spores Survive in Interstellar Space?

How long does it take an organism to come into existence? A human infant takes only about nine months from conception to birth — but it has a complete set of genetic instructions to direct its path. On the other hand, is 200 to 400 million years too short a time to allow the simplest forms of life to evolve out of the pre-biotic chemical “soup” present on the primitive Earth?

For some scientists studying the early Earth, the 200 to 400-million-year gap between when the crust cooled sufficiently to allow chemical evolution and the first clear evidence of living organisms is much too short. Life, they feel, must have arrived on Earth from elsewhere. This idea, termed panspermia, dates back to the early years of this century.

It's a hard hypothesis to test, but recently two astrophysicists at the University of Leiden in the Netherlands — Peter Weber and J. Mayo Greenberg — determined that at least one kind of terrestrial spore could exist in typical interstellar conditions for tens of millions of years. This, they think, is probably long enough to survive a journey from one solar system to another. Their report was published in the August 1 issue of *Nature*.

The spore, *Bacillus subtilis*, was chosen because it is known to be resistant to vacuum. The experimenters subjected it to far-ultraviolet light (2000 Angstroms to 3000 Å) and vacuum UV (1000 Å to 2000 Å) at substantial flux rates and low temperatures (down to 10 Kelvins). They found that while they could effectively kill the spores by bombarding them with UV light between 1000 Å and 3000 Å, the

spores lasted considerably longer at 10 K than at room temperature. Even so, they concluded, 99.9% of the spores would be dead within about 2,500 years after being exposed to the typical interstellar medium.

Taken overall, this doesn't sound good for spore longevity — but the experiment was perhaps overly tough, since spores in space wouldn't necessarily be fully exposed. Weber and Greenberg note two possibilities which could increase spore lifetimes: First, spores could be deposited within dense clouds of gas or dust which would attenuate the UV flux by perhaps a factor of 10,000; and second, spores could accrete molecular mantles onto themselves which would act as UV shields.

Combining these effects and working through the likely range of numbers, Weber and Greenberg estimate that as much as 10% of an initial spore population would be alive and active after 4.5 to 45 million years, “which seems to be long enough for spores to be transported from one solar system to another.”

The authors are careful to note that these results do not answer any of the major questions about panspermia — such as where this life might originate, how it could be removed from its home planet, or what would drive it through space — but they do set some constraints on the required processes.

Comet Astronomy Workshop

On June 17th, the third American Workshop on Cometary Astronomy opened in Tucson at the University of Arizona's Flandrau Planetarium. Sponsored jointly by the International Halley Watch and the *International Comet Quarterly*, these workshops concentrate on techniques of comet observation and recent comet research.

With the long-awaited return of Halley's Comet now underway, a large number of the papers presented at this year's two-day-long meet dealt with this famous visitor.

Two papers came from professional astronomers. Dr. Susan Wyckoff of Arizona State University discussed comet origins and composition, and described CCD observations of Comet Halley made at Mt. Hopkins Observatory during the past observing season. According to Dr. Wyckoff, who is the spectroscopy and spectrophotometry discipline co-specialist of the International Halley Watch, the Mt. Hopkins

observations indicate that the ices in the comet began to sublimate with the comet still as far as 6 astronomical units from the Sun.

Stephen Larson, of the University of Arizona's Lunar and Planetary Laboratory, discussed coma and near-nucleus structure, and described a method he has been using for digital processing of old photos of Halley's Comet in order to discern hood and envelope structure in the coma (see “Mining Old Silver,” page 19, October 1985 issue). He indicated how observations of this nature can help in determining the period and other aspects of a comet's rotation, and issued a plea for more observations of this type during Halley's current return.

Amateur astronomers who presented papers at the workshop included Steve O'Meara of *Sky & Telescope*, who described his visual observations of Halley's Comet using the 24-inch reflector at Mauna Kea this past January. O'Meara also discussed his method of determining the rotation period of Comet IRAS-Araki-Alcock by visual observations of its envelope structure. Next, I presented the results of my visual observations of the Apollo asteroid 1983 TB, widely thought to be the parent body of the Geminid meteors, and which made a close approach to Earth in December 1984.

Then Joe Marcus, editor of the quarterly *Comet News Service*, produced results of his study of the brightness of Halley's Comet in 1910, which he believes indicate that the comet will be brighter than expected during this return. David Levy, co-discoverer of Comet Levy-Rudenko in November 1984, described his approach to comet sweeping, and reminded any would-be comet discoverers in the audience that the most important thing in sweeping for comets is “to observe.”

Two experienced amateur astronomers presented some of the many “how-to's” of comet observing, specifically referring to Halley, but applicable to all comets. Charles Morris, associate editor of the *International Comet Quarterly*, described the techniques of visual observations, and covered such topics as types of observations to be made, equipment and atlases to use, and means of finding out about new discoveries. Mr. Morris also described a few pitfalls awaiting beginning comet observers and discussed the difficulties inherent in making light-curve analyses.

Stephen Edberg, coordinator of the International Halley Watch Amateur Observation Network and author of



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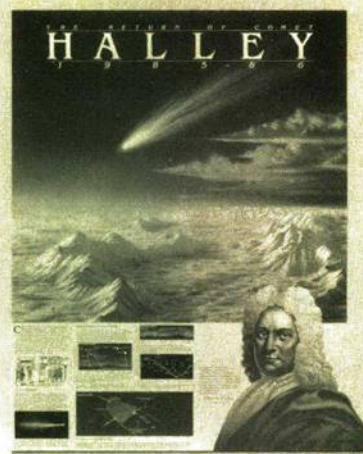
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Hydra cluster of galaxies

the IHW's *Amateur Observers' Manual for Scientific Comet Studies*, described techniques for comet planning and suggested various projects that observers could undertake. In a second paper, Mr. Edberg discussed the progress of the Halley Watch, described the current status of the spacecraft missions to Halley's Comet, and offered a "things to consider" list for those planning to travel to the southern hemisphere to observe the comet.

The last event of the workshop was an open forum, where a panel composed of Edberg, Morris, Levy, O'Meara, Marcus, astrophotographer John Sanford, and myself fielded questions from the audience on such topics as locations for viewing Halley's Comet, observing and photographic equipment, training the eye for detailed observing, and steps to take in case you suspect you have discovered a new comet.

Naturally, the nighttime observing sessions largely featured comet observing! Under the clear, dark, moonless Arizona skies, many observers' telescopes were pointed toward Comet Giacobini-Zinner, on its way to a September 5th perihelion, and on recently-discovered Comet Machholz (1985e). *Alan Hale.*

The Most Distant Galaxies: "Uncharted Territory"

Two astronomers from the University of California at Berkeley

report that 13 newly-discovered radio sources are the most distant galaxies known.

Over the course of two years, Hyron Spinrad and Stanislav Djorgovski used the 4-meter Mayall telescope on Kitt Peak to match high-energy radio sources with their respective faint optical components. To verify that the tiny points of light were indeed galaxies and determine their distances, they also made spectroscopic measurements of their feeble galactic glow.

"Radio emission doesn't carry that kind of information," explains Spinrad. "You need optical data. If you had radio eyes — if you could see the sky in radio frequencies — these things would be bright blobs, and that's all. You wouldn't know how far away they were."

That's where redshift comes in. Big Bang cosmology holds that everything is expanding away from everything else and that velocities increase with distance. If so, the object's spectrum is shifted toward longer (redder) wavelengths. This redshift allows astronomers to calculate the distance to a galaxy. For example, a redshift of 0.4 indicates that the galaxy is moving away at about 32% the speed of light, corresponding to a distance of 1,300 megaparsecs.

"We were working on this for about ten years," says Spinrad. "We started with redshifts of less than 0.5, and have steadily moved upward. We're like pole vaulters. Every year we raise the bar a little higher." All of the 13 galaxies observed in

Spinrad and Djorgovski's study have redshifts greater than 0.7.

The highest redshift observed from a galaxy prior to this study was 1.2, representing a velocity of 66% the speed of light and a distance of 2,600 megaparsecs. The new study raises this figure to 1.81 for galaxy 3C 256, in the constellation Leo. This means the galaxy is moving away from us at a light speed of 78% and that it lies some 3,100 megaparsecs away.

"The present set of galaxies extends the available redshift range for cosmological and evolution tests into previously uncharted territory," wrote Spinrad and Djorgovski in *Astrophysical Journal*. They added that in these galaxies, they are observing conditions as they were nearly two-thirds of the way back toward the beginning of the universe.

Advance in Black Hole Theory

A new idea that black holes may have atmospheres and emit thermal radiation could resolve a 10-year-old puzzle of how a black hole can have an entropy — the measure of an object's internal disorder — far greater than that of any other cosmic body.

Black holes are superdense objects that form when massive stars collapse after exhausting all their thermonuclear fuel. Immense black holes holding the mass of trillions of Suns are thought to exist at the centers of quasars — intensely bright objects at the edge of the observable universe — as well as within galaxies such as our own.

Using the laws of physics, theoreticians have calculated that a black hole's properties should be determined by three quantities: mass, charge, and spin. A major problem encountered in the calculations was that a black hole's behavior didn't seem to fit the Second Law of Thermodynamics, which holds that entropy in the universe is constantly increasing. Since matter falling into a black hole, in effect, vanishes, its entropy appears to be lost — thus decreasing entropy in the universe.

In 1972, Jacob Bekenstein, now at Ben-Gurion University in Israel, speculated that a black hole could have its own entropy and thus behave thermodynamically. Evidence supporting Bekenstein's theory came in 1974, when Cambridge University theorist Stephen Hawking showed that a black hole might emit thermal

radiation. He found that a hole's temperature is not absolute zero, but typically one-ten millionth of a degree above zero; from this, Hawking indirectly inferred the numerical value of a black hole's entropy.

But the physical origin of a black hole's entropy remained a puzzle until recently, when scientists Wojciech H. Zurek of Los Alamos Scientific Laboratory and Kip S. Thorne of the California Institute of Technology created new mathematical models describing the behavior of black holes. They reported their findings earlier this year in the April 20 issue of *Physical Review Letters*.

According to Thorne, "We have shown that a black hole's entropy is a measure of how many ways the hole could have been born and grown to its present size; its entropy is a randomness linked with the hole's unknown history and encoded in a corresponding disorder of the hole's atmosphere."

This atmosphere, first discovered by William Unruh of the University of British Columbia, is a thin region a few meters thick just above the black hole's "event horizon" — the point of no return beyond which matter inexorably disappears. The atmosphere consists of a soup of particles such as photons, neutrinos, and gravitons. According to Unruh, this atmosphere is responsible for the exchange of energy between the black hole and the universe which causes the weak thermal radiation postulated by Hawking.

"We have discovered," said Thorne, "that the black hole's atmosphere plays the same role in the laws of thermodynamics as would any ordinary thermal atmosphere, such as that of the Sun or that in the cylinder of an automobile engine. And, not surprisingly, although the hole's atmosphere possesses an enormous randomness corresponding to its huge entropy, the statistical properties of that randomness are determined uniquely by the hole's mass, charge, and angular momentum."

Thorne continued, "When we realized the role of the black hole's atmosphere, the calculations that explained the hole's entropy became so straightforward that the world's physicists will likely regard them as trivial. But trivial as they may be, they have clarified somewhat the connection between gravity, statistical mechanics, and thermodynamics."

"While it will likely be centuries before we have the technology to study black holes up close to verify

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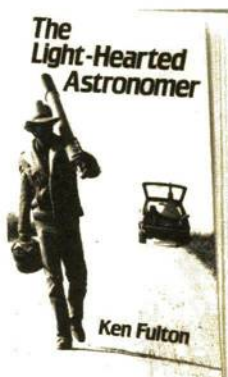
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ASTRO NEWS

the predictions of the laws of physics," said Thorne, "I think they may help theoretical physicists a bit in the struggle to understand the laws of nature."

WIMPs May Solve Solar Mystery

Can something called a WIMP affect anything as powerful as the Sun? Astrophysicists think so.

If they indeed exist, as recent developments in particle physics suggest, WIMPs — Weakly Interacting Massive Particles — may offer an explanation for the observed shortage of neutrinos coming from the Sun.

John Faulkner, professor of astronomy and astrophysics at the University of California, Santa Cruz, and Ron Gilliland of the National Center for Atmospheric Research's High Altitude Observatory have created detailed computer models demonstrating that a small number of WIMPs can effectively lower the temperature at the Sun's center. This in turn inhibits the nuclear reaction taking place deep inside the Sun that produces the brand of neutrinos we detect here on Earth.

Neutrinos seldom interact with other matter, so they can zip through millions of miles of solid material with ease. Those released by the Sun's nuclear reactions stream

through the Sun and into space, passing through nearly everything they encounter.

During almost 20 years of searching, astronomers have detected only one-third as many solar neutrinos as their theories predict.

Over one hundred possible explanations have been raised and nearly all dismissed. "Many of these explanations have terrible and, in some cases, incalculable consequences for other aspects of stellar structure and evolution," says Faulkner. In contrast, WIMPs would only affect the center of the Sun and do not carry disastrous consequences for other stellar regions.

As their name implies, WIMPs interact only weakly with other matter, such as the subatomic particles that exist in dense profusion at the Sun's core. They cannot travel far from the Sun's center because gravity confines them. But because they can move fairly freely within a confined sphere, WIMPs offer a means for redistributing energy throughout the Sun by picking it up at the center and depositing it in shallower regions.

In that manner, WIMPs can smooth out the sharp peak in temperature that computer models indicate exists in the Sun's core. A small swing in temperature greatly affects the nuclear reaction producing the neutrinos, thus it

would take only a very small number of WIMPs to reduce the number of those reactions and in turn reduce the number of neutrinos we find on Earth, reconciling both theory and observation.

Particle physicists have proposed supersymmetry theories to predict the existence of particles that would match the requirements for WIMPs. The photino, a hypothetical supersymmetric partner to the photon, fits the bill nicely.

VB 8B Revisited

When last heard from, van Biesbroeck 8B — VB 8B for short — was generating some terminological havoc. Some saw McCarthy, Probst, and Low's discovery (see *AstroNews*, March 1985) as the first extra-solar planet to be discovered, while others saw it as just a "brown dwarf" — a star that hadn't quite enough mass to ignite its nuclear fires.

Now, three astronomers at MIT (L.A. Nelson, S.A. Rappaport, and P.C. Joss) have reported in the July 4 issue of *Nature* on their stellar evolution calculations. These computer studies show that VB 8B, the smaller of the two objects which make up the VB 8 system, has a mass about 0.04 to 0.08 times that of the Sun, is probably about 0.07 to 0.08 the Sun's diameter, and is best described as a brown dwarf. The

computations also reveal that the force which keeps the star from collapsing is degenerate electron pressure, where the material in the core of the star is so tightly packed — even down to the atomic level — that it cannot shrink any farther.

Nelson, Rappaport, and Joss write that their models for the evolution of these objects show VB 8B reached its present form about 100 million years after condensing from the interstellar medium. It has remained largely unchanged — except for a slow, steady cooling to its present 1360 Kelvins — for most of the history of the Galaxy.

In addition, the authors conclude that the double star system's primary, VB 8A, could also be another low-mass star which failed to "turn on." The problem here is that while VB 8A appears to have the right temperature (about 2400 K), the observations are extremely difficult to make and the possible error is large. Since VB 8A lies so close to the right temperature of a "real" star, it may, in fact, be one.

For future studies, the authors say the Space Telescope should sample a large part of the local dim star population. This will help astronomers draw some firmer conclusions on what happens in the evolution of very low-mass stars, as well as make some predictions about how much mass the Galaxy actually holds.

ASTRO CALENDAR

November 1-2

AAVSO Fall Meeting, Mt. Holyoke College, South Hadley, Massachusetts. Contact: Dr. Janet Mattei, AAVSO, 187 Concord Ave., Cambridge, MA 02138. Phone (617) 354-0484.

November 7-8

SPACE STATION: Gateway to Space Manufacturing and Services, Orlando, Florida. Contact: Anne Phelan, *Space Business News*, 1401 Wilson Blvd., Suite 910, Arlington, VA 22209. Phone (703) 528-1244 or (800) 424-2908.

November 9-10

Deep South Regional Stargaze, Percy Quin State Park, McComb, Mississippi. Contact: Frank W. Loflin II, ALCOR, Jackson Astronomical Association, 280 W. Lorenz Blvd., Jackson, MS 39213. Phone (601) 982-2388 days or (601) 856-3636 evenings.

December 13-15

Winter Star Party, sponsored by the Arkansas/Oklahoma Astronomical Society, Sallisaw Creek Recreation Area, Oklahoma. Contact: Bob Moody, 109 S. Cedar, Sallisaw, OK 74955. Phone (918) 775-3739.

February 7-10, 1986

Second Annual Winter Star Party, sponsored by the Southern Cross Astronomical Society, Everglades National Park, Florida. Contact: Richard A. Fagin, P.O. Box 152, Miami, FL 33197. Phone (305) 233-5165.

April 18-19

Wisconsin Society of Science Teachers Annual Spring Convention, Appleton, Wisconsin. Contact: Floyd R. Henschel, 504 W. Maple Ave., Beaver Dam, WI 53916. Phone (414) 885-4415 weekdays or (414) 887-1215 evenings.

April 19

Astronomy Day. For more information, contact: Gary Tomlinson, Astronomy Day Coordinator, Astronomy League, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503. Phone (616) 456-3985.

Meeting notices to appear in *AstroCalendar* must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

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ANNOUNCEMENT — The Auburn Astronomical Society meets on the first Friday of each month at 7:30 p.m. in room 128 of Parker Hall on the Auburn University campus. Join us for interesting programs, dark-sky observing, and other activities. Contact Russell Whigham, 123 Carter St., Auburn, AL 36830.

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Breezes, Bangs, & Blowouts: Stellar Evolution Through Mass Loss

by David Darling

Part 2

In the previous article (September issue), we examined the fate of stars similar to the Sun. Let's now look at what the future holds for the stellar heavyweights.

Evolution Through Attrition

An important way in which stars lose mass and evolve rapidly is through a stellar wind. "Breezes" that blow over millions of years can actually carry away more matter than the abrupt bang of nebular ejection. But the significance of stellar winds varies a lot from star to star and changes during a star's lifetime.

Red giants, as we've seen, are particularly susceptible to mass loss through stellar winds following the disappearance of their coronas. Estimates vary as to the extent of this mass loss, which also depends on characteristics of the particular star. But it seems safe to conclude that some red giants shed upwards of one solar mass over several million years.

In certain cases, this mass loss could have significant evolutionary effects. It might, for example, enable an otherwise supernova-doomed star to squeak under the minimum mass at which it would explode. In other instances, although it might not save a heavy star from going supernova, it could result in a lighter remnant object that ends its days as a neutron star rather than as a totally-collapsed black hole.

Stellar winds can also affect the immediate environment of red giants. In particular, if the material that escapes in the wind is dense enough, it may cool to form small grains of dust as it moves away from the star. Eventually, the dusty ejecta can settle into an enormous opaque circumstellar shell. The shell is naturally much cooler than the surface of its parent star and therefore emits radiation at much longer wavelengths. This is almost certainly the cause of the "infrared excess" seen in the spectrum of many highly-evolved red giants (see "The Vanishing Act of Carbon Giants," *ASTRONOMY*, June 1982).

The appearance of a circumstellar shell is also a telltale sign that the central red giant is getting senile. In the case of very massive stars, the dusty shell is especially suggestive. Astronomers have recently been looking closely at the condition of some older, heavier, dust-encircled stars in our region of space. For instance, much attention has focused on Betelgeuse and Eta Carinae for the simple reason that these colossal stars seem to be right on the verge of going supernova. Betelgeuse, in particular, is blowing a stellar gale, losing a Sun's worth of matter every 100,000 years.

Betelgeuse also has a vast circumstellar shell with a chemical composition suggestive of large amounts of nitrogen in the star's outer atmosphere. Eta Carinae, one of the most massive and luminous stars known, reveals a high nitrogen excess in a gas cloud ejected about 200 years ago. Significantly high abundances of nitrogen have also been found in the 300-year-old Cassiopeia A supernova remnant. This indicates that Betelgeuse, Eta Carinae,

and Cas A are at almost identical stages of evolution.

But do stars have to be poised on the edge of oblivion in order to blow gale-force stellar winds? Not at all. Some of the very youngest stars in the Galaxy are also some of the most active in terms of mass loss through stellar winds. These are the O-type stars: the hottest and brightest of the main sequence stars, with surface temperatures exceeding 25,000 K and luminosities over 10,000 times that of the Sun. The radiation pressure is so intense in the atmospheres of O-type stars (radiation, rather than convection, is the dominant core-to-surface heat transport process in these objects) that it can expel material at up to $\frac{1}{10,000}$ solar mass per year. In extreme cases, heavy young stars can lose 10 solar masses from their atmospheres in less than a million years. The entire future of an O-type, in fact, is strongly influenced by how much mass it sheds before its vigorous stellar wind dies down.

What effect does the outflow of matter from an O-type star have on its surroundings? This is a problem that astronomers have only begun to tackle, but already the results are fascinating.

The formation of massive stars like the O-types is obviously favored by the presence of clouds rich in gas and dust. As a result, O stars are generally found embedded in regions of dense nebulosity. When the fierce wind from one of these stars begins to blow, it collides with the thick surrounding interstellar medium and may set up a very powerful spherical shock front. Matter compressed along the shock front forms into a thin ring-like nebula — an interstellar "bubble." (This name was coined by astrophysicists J. Castor, R. McCray, and R. Weaver, who first described the physics of this interaction in a theoretical paper a decade ago).

Bubbles are common around O stars, but they've also been found in association with Wolf-Rayet stars — a rare species first noticed by the French astronomers C.J.E. Wolf and G. Rayet in 1827. What's more, because the stellar winds of Wolf-Rayet stars may be 10 to 100 times more intense than those of the big O-types, they tend to produce much stronger shock fronts and correspondingly more prominent nebulae.

Wolf-Rayet stars are oddballs — difficult objects to fit into the stellar jigsaw puzzle. They're characterized by very high surface temperatures (50,000 K to 100,000 K) and the presence of super-scale stellar winds. Although some appear related to O and B-type stars (they're often found physically associated with these objects), others pop up as the central stars of planetary nebulae — suggesting a totally different evolutionary track.

A supernova explosion is the most dramatic way for a star to lose mass. This supernova remnant, called the Gum Nebula (after its discoverer, Colin Gum), lies in the constellations of Puppis and Vela. The star exploded about 10,000 years ago. Photo © UKSTU, Royal Edinburgh Observatory.



It seems, in fact, that there are two distinct subgroups of Wolf-Rayet stars. The first consists of luminous high-mass Population I stars that are clearly related in some way to the O-types. The second includes much dimmer and lighter objects that fall more into the older Population II category. Both families of Wolf-Rayet stars can be associated with circumstellar nebulae, but there are very significant differences between the thin bubbles of Pop I Wolf-Rayet stars and the planetary nebula shells of their Pop II cousins.

The high surface temperatures of the Wolf-Rayet stars suggest that we're dealing with the exposed cores or inner regions of stars that have shed their cooler outer layers. We're confident that this is the case with the planetary nebula central stars. There's also evidence to support the idea the Pop I Wolf-Rayet stars may be massive O-types that have shed their hydrogen-rich atmospheres. On the other hand, the intense stellar winds indicate the presence of powerful radiation pressures in the upper levels of Wolf-Rayet atmospheres. This also suggests — because of their high mass loss rate — that Wolf-Rayet stars represent a fairly short-lived evolutionary phase. This is backed up by the apparent paucity of these objects in our Galaxy — at present only about 200 are known.

A recent general model for planetary nebulae uses stellar winds as the primary generation mechanism. According to this idea, a circumstellar halo develops around the nucleus star. The stellar wind gradually picks up speed as successively hotter layers of the star are exposed. Finally the carbon-oxygen core is laid bare, giving rise to an intense high-speed wind that slams into the existing halo from inside. The resultant shock wave heats and ionizes the circumstellar material, producing the familiar planetary form.

Back on the main sequence, the cooler B and A-type stars also experience mass loss through stellar winds, but their internal radiation pressures are well below those of the O-types or Wolf-Rayet stars and the effect is much less pronounced. Still further down the main sequence toward the cooler end, the evolutionary tracks of stars are virtually unaffected by "evaporation" in stellar winds. In the case of the Sun, for example, only one part in 10^{14} of the solar mass is blown away each year — barely enough to dissipate 0.01% of the Sun's total mass over a 10-billion-year main sequence lifetime.

Stellar Blowouts: Type II Supernovae

The gentle breezes of lightweight main-sequence stars can waft away material for billions of years with virtually no evolutionary consequences. At the other end of the activity scale, however, aging heavyweight stars can suddenly explode and in the process undergo the most rapid and profound evolutionary transition. These explosions are called Type II supernovae (we'll consider Type I later). What causes them? What is it about unusually heavy stars that makes them prone to such colossal stellar blowouts?

Most stars never manage to ignite the carbon-oxygen cores they eventually acquire as red giants. After a spell of hydrogen and helium shell burning, they modestly cast off their atmospheric cloaks as planetary nebulae. Heavy stars, on the other hand, are much better at exploiting their remaining supplies of fusion material. They can put a far harder squeeze on their cores, boosting core temperatures to the point at which carbon burning begins.

If a star is massive enough after the carbon flash stage, it can continue to ignite the main fusion products of successively heavier elements — carbon, oxygen, silicon, and so on — up to the point where its core is filled with the nuclei of iron. Then it must stop because fusing iron takes more energy than the fusion reaction gives back.

So what happens next? Again, mass is the critical factor. According to theory, if the star's iron core is lighter than 1.4 solar masses — the Chandrasekhar limit — it can stabilize as a white dwarf and start on a long cooling path toward oblivion. But if the core weighs in at more than 1.4 solar masses, it's forced to undergo a sudden and quite remarkable transition.

Starting as a planet-sized ball of iron, the core collapses in

Stellar matter is never really lost — it eventually collects in clouds of gas and thick banks of dust where it collapses into proto-stars, heats up, begins thermonuclear reactions, starting the process anew. Photo of NGC-2264 and S Monocerotis © Anglo-Australian Telescope Board.

about $\frac{1}{10,000}$ of a second to become a 20-kilometer-diameter ball of densely packed neutrons! Beyond this stage, our theories are incomplete. The core may bounce back to become slightly larger before settling to a final equilibrium state. In the process, an outward-moving shock wave would be generated at the base layers of whatever remained of the star's atmosphere.

Recent calculations, though, point to only a small core bounce — not sufficient to eject material. What's more likely is that the outer portions of the star — falling in at supersonic speeds — themselves produce a shock wave in the region of impact with the high-density core.

This shock wave may be strong enough to trigger various runaway thermonuclear reactions in the atmospheric envelope. Of these, the most important is oxygen-to-silicon fusion which occurs at a temperature of around 1 billion degrees. The catastrophic ignition of fusion materials in the envelope may be sufficient to eject some of the star's atmosphere into space at speeds up to 10,000 kilometers per second.

Exactly how much mass is blown off during a Type II event is unknown. Strange particles called neutrinos are produced as the shock wave collides with the envelope material. These — together with dissociating iron nuclei — may soak up much of the explosive energy. Instead of being blasted into space, most of the stellar envelope may end up in the core. If this happens, the core could easily exceed the so-called Landau-Oppenheimer-Volkov limit (around 3 solar masses) and disappear permanently into a self-made black hole.

At one time, astronomers thought that up to 90% of the initial mass of heavyweight stars could be shed in a Type II blowout. Today, estimates favor a value between 10% and 20%. Indeed, some present calculations have trouble predicting any explosive activity at all! Remember, too, that between the time of birth and the time when an overloaded iron core seals its cataclysmic fate, there are various ways a star can shed mass. Stellar winds and nebular ejections — not to mention the effects of a companion star — can crucially influence a star's evolutionary course.

This makes it very difficult to predict the future of massive stars with confidence. Intermediate mass stars — say, in the 4 to 10 solar mass range — are especially problematic; their fate hangs in the balance throughout most of their lives. Only when a star's core attains its final mass — when there's no possibility of further mass loss or gain — is its ultimate destiny sealed.

Binary Blowouts:

Novae and Type I Supernovae

At their peak, novae can surge to 10,000 to 1,000,000 times their pre-novae brightness. For a short time, they can rival the brightest stars in the Galaxy. Yet novae are not stellar eruptions on the scale of supernovae — or even of planetary nebulae. In fact, the total extent of their mass loss is rather modest: only about $\frac{1}{10,000}$ of a solar mass. So what are they? And how do they get so bright if they don't eject a lot of matter?

Novae are a phenomenon that occurs only in binary systems. They require, in fact, a special type of binary — one where a white dwarf is very closely coupled to a cool, expanding subgiant.

Here's the scenario. The white dwarf has exhausted its original supply of nuclear fuel. Its larger companion has recently left the main sequence and is now moving toward its red giant phase. The larger star's atmosphere has expanded to the point where it's strongly influenced by the gravitational pull of the dwarf. Matter is sucked from the large star's bloated atmosphere into an accretion disk centered on the white dwarf.

Material from the accretion disk — rich in hydrogen from virgin regions of the larger star — spirals down onto the white dwarf. Impact with the dwarf heats the small star's surface. More





NGC-6302 is an unusual emission nebula in the constellation Scorpius that has ejected material in two directions. What's unusual is that spectroscopic studies show this material has a much higher velocity than that found in most emission nebulae. Photo © Anglo Australian Telescope Board.

material piles on and the surface temperature of the dwarf gradually increases. At the same time, the heating gives rise to convection currents in the outer layers of the dwarf which circulate old carbon "ashes" through the newly-acquired hydrogen. When the surface temperature hits 20 million degrees or slightly higher, hydrogen and carbon fusion reactions begin explosively. The result is a nova outburst. Although only a relatively small amount of mass is involved, its runaway fusion — like a colossal thermonuclear bomb, in fact — is enough to turn the white dwarf into a stellar celebrity for a few glorious days or weeks.

Once triggered, the nova "skin" of the white dwarf is ejected at very high speed — several thousand kilometers per second. Years later, we may see it as a fragmented shell around the parent star.

So long as the bloated companion sheds material, the process may be repeated over and over again, giving rise to a recurrent nova. But not all of the captured material is necessarily regurgitated with each event. Gradually, the white dwarf's mass increases. It may eventually reach the Chandrasekhar limit of 1.4 solar masses. Then a familiar pattern ensues. The white dwarf shrivels, in the twinkling of an eye, to become a neutron star. If sufficient energy is injected into the star's collapsing outer layers, a runaway thermonuclear reaction is triggered and the stellar envelope is launched spaceward at high speed. This may explain the spectacle of a Type I supernova — an event brighter and rarer than its Type II cousin.

Close binaries are fertile territory for events that knock stars

from their original evolutionary courses. The components of binaries put a lot of gravitational stress on each other, and that stress manifests itself in its effect on the more loosely-held outer parts of a star. If the association is close enough and at least one of the components has an extended atmosphere, then conditions are ripe for the loss or transfer of mass.

Some binary systems — the so-called contact binaries — are so close that their component stars actually touch. A sort of communal atmosphere envelopes both stars and there's continual and mutual exchange of matter. Other close binaries — the semi-detached variety — are more lopsided. In these, matter flows all one-way — typically from a giant star with a huge cool atmosphere to a more compact, parasitic companion.

Whatever the details of a particular close binary, though, one thing is clear. A star born in close association with another is likely to evolve very differently than if it were alone. In fact, the evolutionary effect from the mass that a star gains or loses because of a partner may outweigh all the other influences we've discussed. If the star is initially a heavyweight, it may later have a good portion of its matter snatched away by its companion. On the other hand, it may begin life as the lighter component, only to put on weight at the expense of its mate and end its days as a neutron star or a black hole.

Mass loss and gain are the wild cards of stellar evolution. They're the major factors that can cause a star to wander from its original evolutionary track and can radically alter its final destiny. We're only beginning to understand the breezes, bangs, and blowouts through which stars alter their life courses, and through which raw material is fed back into the galactic star-making machinery.

David Darling holds a Ph.D. in astronomy and is a computer consultant and freelance science writer. His last ASTRONOMY article was "Spectral Visions" in the August and September 1984 issues.

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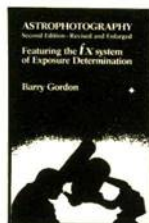
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A Rare View of Mare Orientale

by
Michael T. Kitt

Mare Orientale — the *Eastern Sea*.

This is the Moon's most notorious feature — a now-you-see-it, now-you-don't phantom that's the hardest one of all to tick off on your "must see" list.

The center of Mare Orientale lies just a bit more than 90° from the center of the lunar disk, straddling the Moon's western limb about 20° south of the lunar equator. (Why is the Eastern Sea on the western part of the Moon? The old astronomical conventions for lunar east and west, under which the mare was named, were switched about 20 years ago to match familiar terrestrial geographic directions. This was so astronauts on the surface would be facing east when looking toward sunrise.) You never see it clearly — the Eastern Sea always hovers on the edge of invisibility, heavily foreshortened and oblique. But this November, for the first time since the winter of 1967, you'll get a good view of Mare Orientale — the last until after the turn of the century.

Planetary astronomers think Mare Orientale is the youngest of the lunar basins. It formed after a giant meteorite slammed down, excavating cubic miles of rock, and carved out a basin which subsequently filled with lava. Viewed from above, at least three concentric ring-mountains surround the central impact point. The most prominent rings, the Montes Rook and Montes Cordillera — together with the intervening strips of dark mare material, Lacus Veris and Lacus Autumnae — extend partway onto the near side of the Moon and are frequently visible near the limb. The central mare itself, however, lies fully on the far side of the Moon and can be observed only when lunar librations are most favorable.

The easiest way to envision these librations is to imagine the Moon slowly nodding and shaking its head simultaneously. A full explanation of librations goes well beyond the scope of this article but briefly, librations in longitude — an east/west shake of the lunar head — have an average period of 27.55455 days. Therefore the Moon's

eastern and western edges alternately swing toward our view and then away about every two weeks. Librations in latitude — nodding north and south — have an average period of 27.21222 days. Because Mare Orientale lies just beyond the southwestern limb, it can be seen only when librations roll the Moon toward the east and north.

Since the two librations have slightly different periods, they reach maximum together only infrequently and each month thereafter get progressively out of step. In fact, it requires almost exactly 6 years to cycle from one favorable libration to the next. So why does it take so long between viewing opportunities? There are a few snags that prevent us from seeing Mare Orientale every 6 years:

After one favorable apparition, the next always occurs when the Moon is waxing gibbous and the Sun has not yet risen over Mare Orientale. The synchronization after that (at the 12-year point) always occurs very close to New Moon, when nothing is visible. It's not until after 18 years that the original synchronization repeats. The exact period is 6585.32 days — this is the famed "saros" cycle, which Chaldean astronomers discovered thousands of years ago. The saros is the period after which an eclipse repeats almost precisely.

Since the periods of libration in latitude and longitude differ by only 0.34 days, it's tempting to conclude that every 18 years we ought to have a long period during which the two librations are nearly synchronized and the mare would be favorably placed for viewing. While it's true that the librations remain closely in step for the better part of a year, there is another complicating snag:

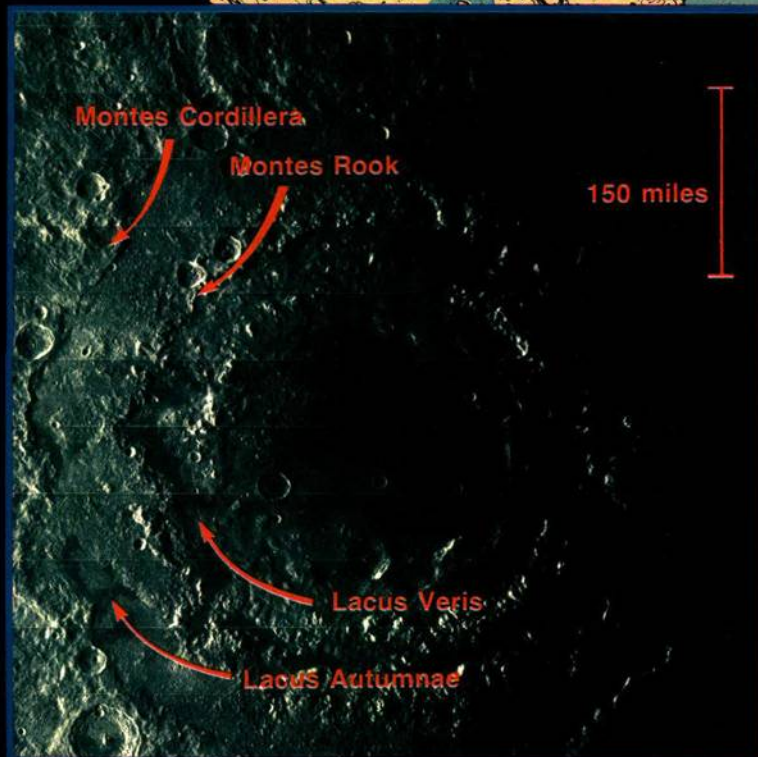
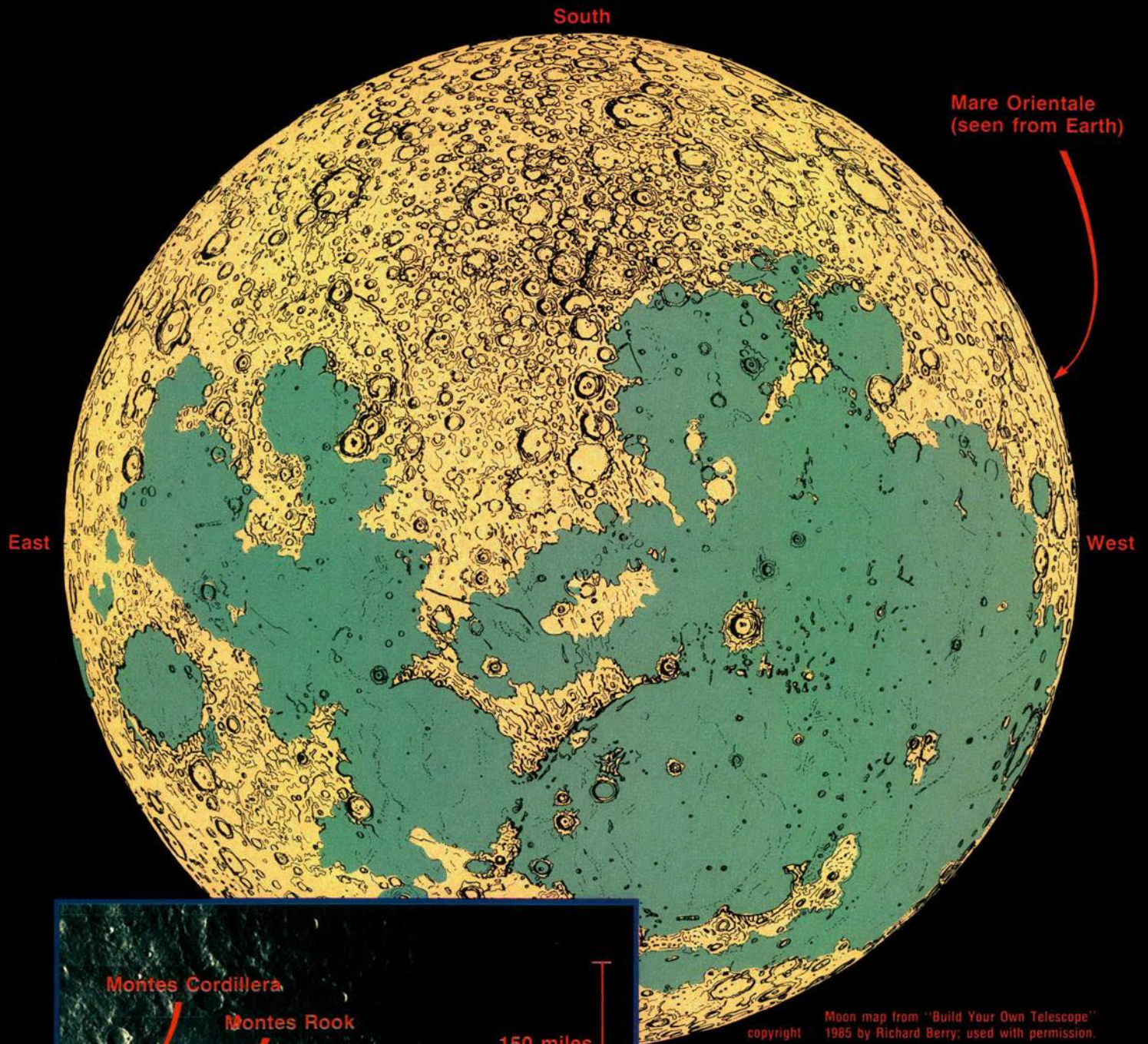
Due to orbital effects, the maximum amount of libration in longitude varies on a cyclical basis and can be as small as 5° or as large as 8° . Maximum librations that rotate the western limb into view happen only when Full Moon and apogee occur at nearly the same time. Although this comes roughly every $7\frac{1}{2}$ lunar months, it has to occur near the time when the saros

cycle places the mare in the right location. This strict requirement means that viewing conditions for Mare Orientale tend to deteriorate rapidly on either side of the optimum viewing date.

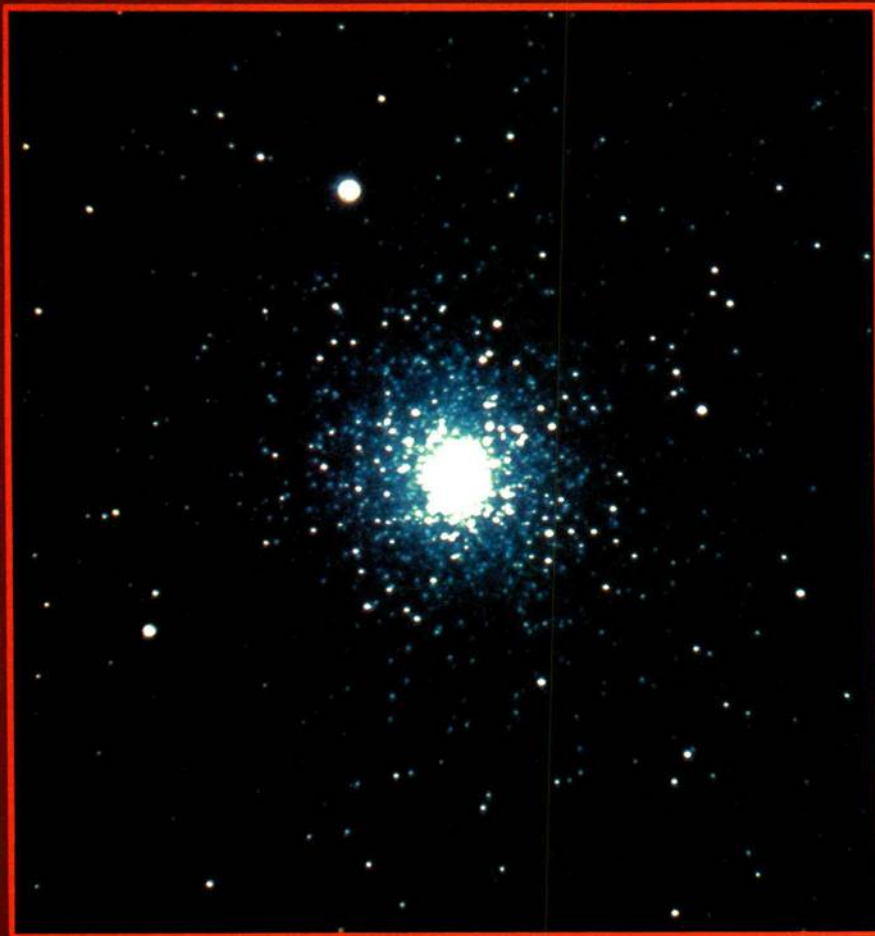
The upshot of all this mumbo-jumbo is that your best views of Mare Orientale will occur this year on the morning of November 6th. (Bad weather alternates are November 5th and 7th and December 3rd and 4th.) You can observe with binoculars, but a telescope will give the most satisfactory views. Low magnifications are preferable to high ones because they enhance the contrast between the dark mare patches and the lighter surrounding highland areas. Low magnifications also help minimize the distortion caused by looking out through a turbulent terrestrial atmosphere. Use a deep yellow filter or a polarizer to cut the glare of the Moon and further enhance contrast.

When you finally observe this scarce-seen wonder, take a journey of the imagination back three billion years. What would it have been like to witness a 10-mile planetesimal hurtling out of the black lunar sky? It streaked down, crashed onto the already-cratered landscape, and dug a miles-deep pit, which it filled — briefly — with incandescent rock. The ground for hundreds of miles around was shaken to pieces. Waves of energy raced outward, pushing, stretching, and piling up the rocks in fantastic shapes. Today, the Rook and Cordillera Mountains stand as mute evidence of this violence. Then, over all rained down a thick blanket of debris, kicked high in the initial blast. A little later, when the Moon got around to it, lava came quietly oozing up through the broken, shattered rock and paved over parts of the impact site. Mare Orientale was born.

As space photography has demonstrated, this is one of the showcases of the solar system. Yet it is certainly the least observed of the major celestial sights. Why not catch it during its last good apparition of the twentieth century?



Mare Orientale
(seen by spacecraft)



Left: M-15 is one of the sky's brightest globular star clusters. Below left: NGC-7814, a 12th magnitude edge-on galaxy, shows its equatorial dust lane in 6-inch telescopes under a dark sky. Below: Stephan's Quintet, a group of interacting galaxies, appears as a misty patch of light in backyard telescopes. Below center: Although it has a low surface brightness, NGC-7479 is one of the sky's finest barred spiral galaxies. Bottom: NGC-7331 is a 10th magnitude galaxy resembling a fainter version of M-31. All photos by Bill Iburg.



Pegasus

Peg

Pegasi

Equuleus

Equ

Equulei

Dominating the autumnal evening sky is the large asterism known as the Great Square. Composed of four bright stars — Markab, Scheat, Algenib, and Alpheratz — the Great Square is the centerpiece of **Pegasus** the Winged Horse, easily recognizable because it is surrounded by mostly blank sky. Pegasus contains more than the Great Square, however: it is far enough away from the Milky Way that it contains plentiful galaxies for backyard observing.

But the best deep-sky object in Pegasus is the bright globular cluster **Messier 15** (NGC-7078). It is quite easy to find, lying some 4° northwest of Enif (Epsilon [ε] Pegasi). Appearing as a magnitude 6.4 “fuzzy star” in finder telescopes or binoculars, M-15’s appearance changes when viewed with a 4 or 6-inch telescope — at low power (40x) the globular’s 12.3’ disk appears as a uniformly illuminated glow, while high power (100x) resolves its edges into dozens of tiny pinpoint stars. Larger telescopes do even better: a 12-incher at 175x resolves stars across M-15’s disk to create a three-dimensional effect. A 17.5-inch telescope reveals hundreds of yellow stars — while small scopes tend to give a gray or greenish tint to the cluster.

M-15 is an unusual globular for several reasons. It is an intense X-ray source, leading astronomers to believe that it contains a central black hole “engine” that feeds off material from stars which stray too close to the cluster’s core. (Even in a backyard telescope, you’ll notice that M-15 has one of the most intensely brilliant cores of any globular.) It contains a huge number of variable stars — 110 in all; unfortunately, most are faint RR Lyrae types with short periods and amplitudes, making observing their brightness changes difficult. Curiously, M-15 is the only

globular cluster containing a known planetary nebula, Pease 1. The nebula measures 3” across, glows dimly at magnitude 14.9, and is surrounded by hundreds of stars; it is impossible to pick out with backyard telescopes.

Near M-15, about 3.3° northeast of Enif, is the erratic variable star **AG Pegasi**. This bizarre object is one of the brightest of the so-called symbiotic stars, systems showing bright hydrogen lines in their spectra. Astronomers believe that AG Peg contains a Wolf-Rayet star and a reddish M giant. The Wolf-Rayet object resembles the nucleus of a planetary nebula, and is surrounded by a dim blanket of nebulosity.

AG Peg has an unusual history of variability. Up until about 1850, it appeared as a steady 9th magnitude star. But between 1850 and 1870, it brightened to 6th magnitude. Then AG Peg remained relatively stable until 1920, when it began a rapid succession of spectral changes and gradual fading. Although it has a semi-regular period of 830 days, AG Peg now appears fairly stable and shines around 9th magnitude.

Pegasus contains a multitude of bright galaxies for backyard telescopes. The finest is **NGC-7331**, a 10th magnitude Sb-type spiral that looks like a miniature version of M-31, the Andromeda Galaxy. (Both M-31 and NGC-7331 are similar types of objects, but appear different because NGC-7331 is about 20 times

more distant.) Lying 4.3° north and slightly west of the bright star Eta (η) Pegasi, NGC-7331 is visible in finder scopes under a dark, moonless sky. A 3-inch telescope shows this galaxy as a small oval of gray-green light spanning about 5’. A 6-incher at high power reveals a bright, roundish nucleus enveloped in the oval disk. Under good conditions a 10-inch scope shows a faint, uniformly-lit halo of nebulosity — NGC-7331’s spiral arms, which measure 10.7’ x 4.0’.

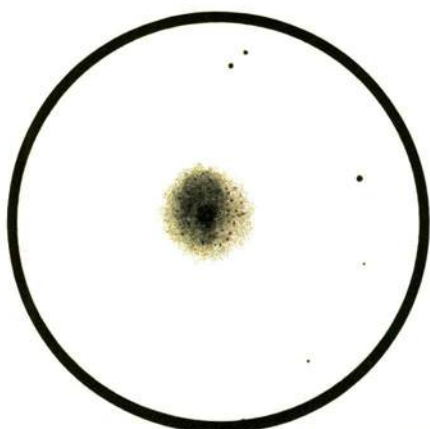
Just ½° south-southwest of NGC-7331 is a faint group of galaxies collectively known as **Stephan’s Quintet**, after M.E. Stephan, who discovered the group in 1877. The brightest member, NGC-7320, is a magnitude 12.7 spiral, the only object in the area visible with a 4-inch scope. The other members are 13th magnitude galaxies: NGC-7317, an elliptical; NGC-7318A, a peculiar elliptical; NGC-7318B, a peculiar barred spiral; and NGC-7319, another peculiar barred spiral. Although all five galaxies appear intertwined, redshift measurements show that the group lies about 90 megaparsecs’ distant, while NGC-7320, the brightest member, is located a mere 13 megaparsecs away and simply lies along the same line of sight. Backyard telescopes generally show this group as a fuzzy patch of light some 10’ across, although 10-inch or larger scopes show NGC-7320 as a bright oval and resolve individual nebulous spots representing the light from



Keith Ward

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

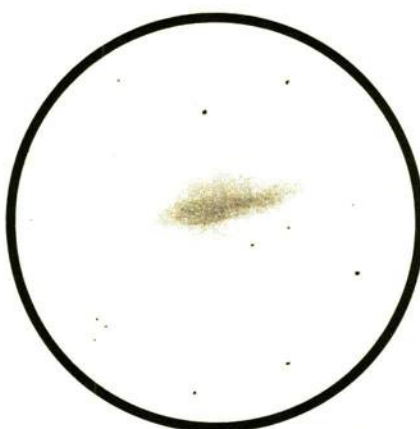
M-15



8-inch f/10 SCT
50X

Sketches by David J. Eicher

NGC-7331



8-inch f/10 SCT
50X

four distant galaxies.

About 2° south and slightly west of the bright double star Pi (π) Pegasi is the little galaxy **NGC-7217**. An Sb-type spiral with tightly-wound arms, NGC-7217 shines at magnitude 10.2 and appears nearly face-on, measuring 3.7' x 3.2' across. It has a relatively high surface brightness, and stands out as a fuzzy spot even in 2-inch scopes. Larger telescopes show a bright core surrounded by a circular gray haze of nebulosity.

Ten degrees due south of the NGC-7331/Stephan's Quintet area is another bright galaxy, **NGC-7332**. Shining at 11th magnitude and extending 4.2' x 1.3', NGC-7332 is a highly elliptical E7 galaxy that is visibly lens-shaped in backyard telescopes. It has a brilliant central condensation and tiny nucleus with a smooth, evenly-illuminated streak of nebulosity crossing through it. In the same field of view is the fainter galaxy NGC-7339, an edge-on barred spiral

dimly glowing at 13th magnitude.

The area of sky below the Great Square also holds several bright galaxies. One is **NGC-7448**, a magnitude 11.7 Sc spiral lying 1½° northwest of Markab (Alpha [α] Pegasi), the star at the southwestern corner of the Square. NGC-7448 measures 2.7' x 1.3' across and exhibits a bright nucleus surrounded by an irregular faint haze. **NGC-7479**, found about 3° south of Markab, is a beautiful barred spiral. It shines at magnitude 11.0, measures 4.1' x 3.2' across, and has a bright core recognizable as a galaxy in scopes as small as 4-inches' aperture. An 8-incher shows NGC-7479's bright core encapsulated in a faint glow which seemingly sprouts two low surface brightness spiral arms winding their way into an oval from both sides of the nucleus. Because it is bright and more-or-less face-on to our line of sight, NGC-7479 is one of the best examples of a barred spiral galaxy. In this same area is the pair of galaxies **NGC-7619** and

NGC-7626, the brightest members of the Pegasus I cluster, a small group of galaxies 50 megaparsecs away. NGC-7619 is an 11th magnitude elliptical some 2.9' x 2.6' across; NGC-7626 is a elliptical measuring 2.5' x 2.0' and shining at magnitude 11.2. Both galaxies lie in the same high-power field and appear as fuzzy splotches of light devoid of detail.

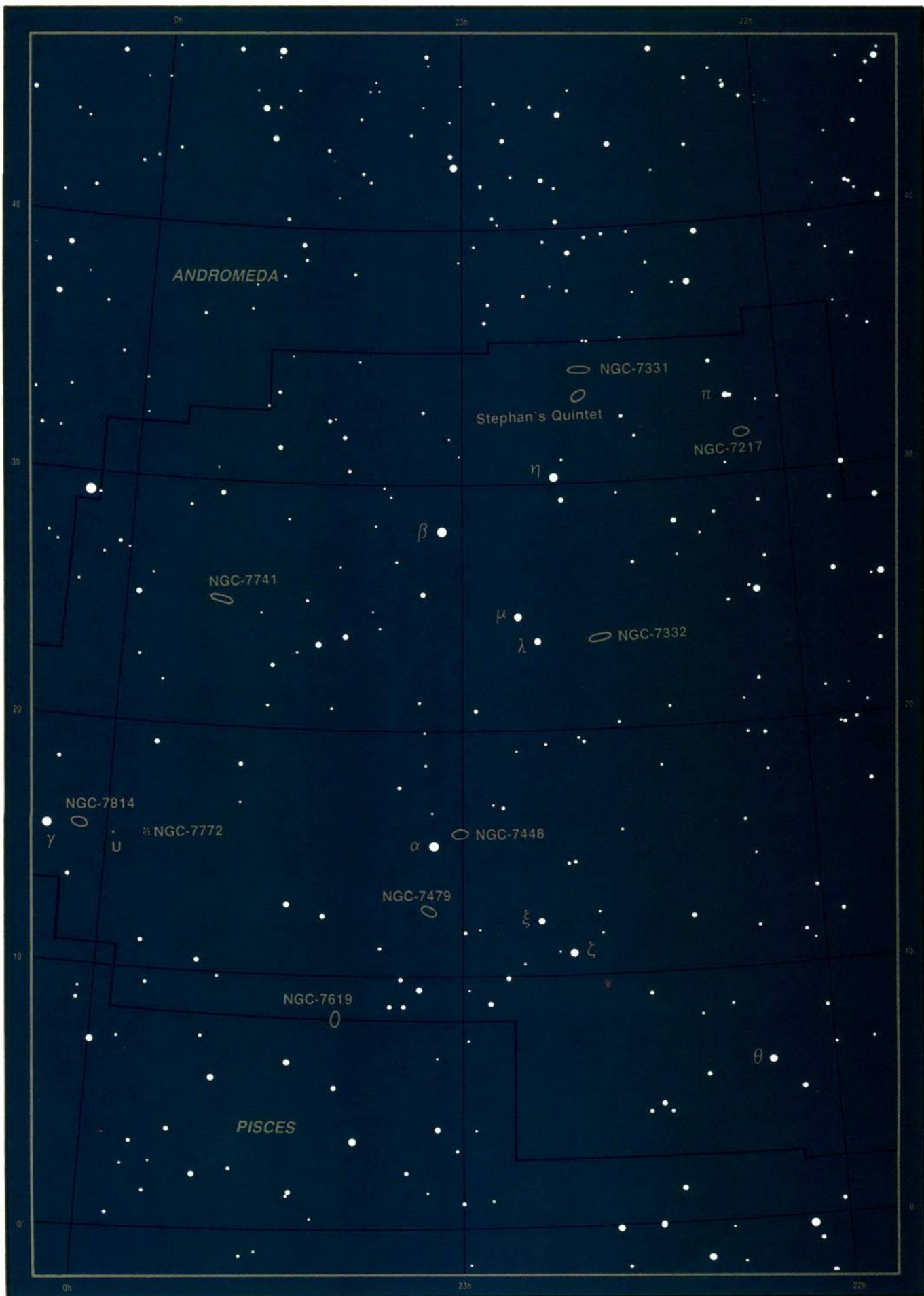
NGC-7741 is an 11.4 magnitude barred spiral lying within the Great Square. It spans 4.0' x 2.8' and is visible in large finder scopes as an elongated patch of misty light; small telescopes show a bright nucleus surrounded by a dim halo of nebulosity. Also inside the Square is a group of three diverse objects. **NGC-7814**, some 3° northwest of Algenib (Gamma [γ] Pegasi), is a bright edge-on Sb-type spiral. It glows at magnitude 10.5 and measures 6.3' x 2.6', making it easily visible as a spike of nebulosity in 3 or 4-inch scopes. A good 6-inch telescope at high power shows the galaxy's broad equatorial dust lane, which appears to split NGC-7814 in two. A degree west of this galaxy is the variable star **U Pegasi**, an eclipsing binary. This star varies between magnitudes 9.2 and 9.9 over a very short period — about 9 hours — so that observing it early and late during the same night may show significant changes. A degree west of U Peg is the small open cluster **NGC-7772**, a group of 7 stars of magnitude 11 and fainter.

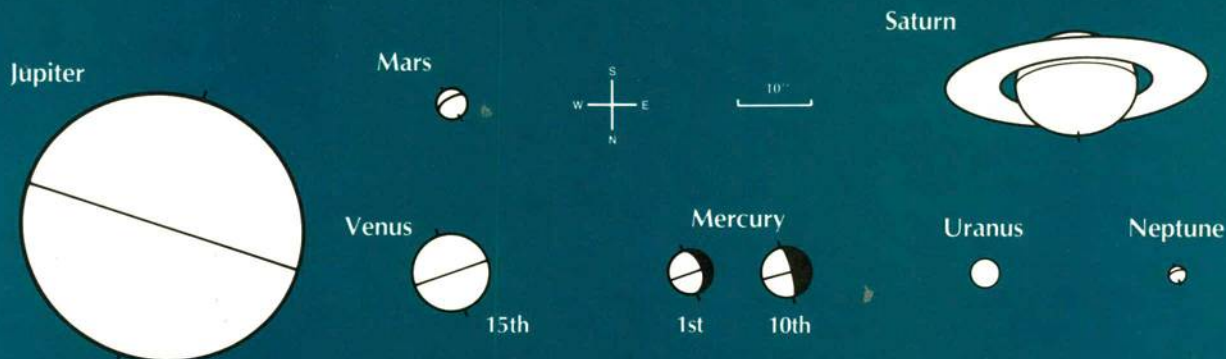
Equuleus the Colt — a tiny constellation due west of Enif — doesn't cover much sky, but it does contain **Delta (δ) Equulei**, a close double star with a rapid orbit. Composed of twin 5th magnitude stars, Delta Equ completes one orbital revolution in just 5.7 years. Closest approach occurs again during 1987, when the two stars will be separated by only 0.35". At present, this star is a difficult object for backyard scopes, but splitting it makes a fine test for large, high-resolution instruments.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.	H
NGC-7814		§	0h 03.3m	+16°09'	10.5	6.3'x2.6'	Sb-
Delta (δ) Equ		★²	21h 14.5m	+10°00'	5.5	0.3"	
NGC-7078	M-15	●	21h 30.0m	+12°10'	6.4	12.3'	
AG Peg		IV	21h 51.1m	+12°22'	6.4↔8.2	Irr	
NGC-7217		§	22h 07.9m	+31°22'	10.2	3.7'x3.2'	Sb-
NGC-7331		§	22h 37.1m	+34°25'	9.5	10.7'x4.0'	Sb
NGC-7332		0	22h 37.4m	+23°48'	11.0	4.3'x1.3'	E7
NGC-7448		§	23h 00.1m	+15°59'	11.7	2.7'x1.3'	Sc
NGC-7479		§B	23h 04.9m	+12°19'	11.0	4.1'x3.2'	SB(b)+
NGC-7619		0	23h 20.2m	+ 8°12'	11.1	2.9'x2.6'	E1
NGC-7741		§B	23h 43.9m	+26°05'	11.4	4.0'x2.8'	SB(c)
NGC-7772		0	23h 51.0m	+20°09'	10	1.6'	
U Peg		EV	23h 55.4m	+15°40'	9.2↔9.9	0.37d	

H = Hubble classification type for galaxies

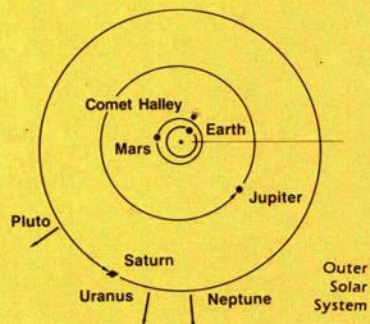
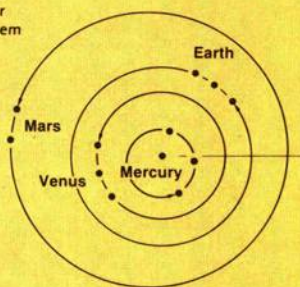
★²	Double Star
EV	Eclipsing Variable
IV	Irregular Variable
0	Open Star Cluster
●	Globular Star Cluster
§	Spiral Galaxy
§B	Barred Spiral Galaxy
0	Elliptical Galaxy





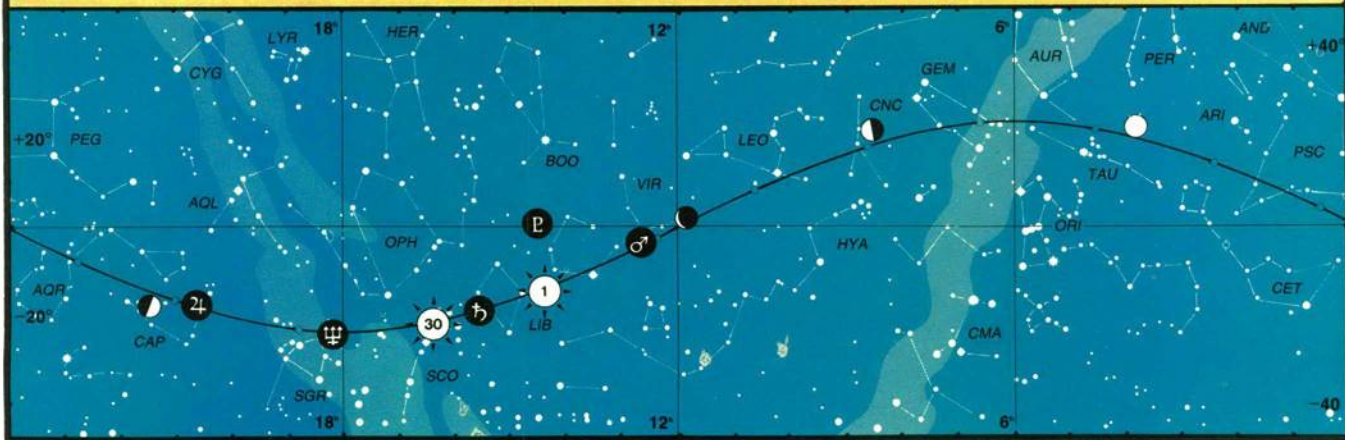
	Date	Mag.	Angular Size	% Illum.	Distance (AU)		Longitude:		R.A. (2000.0)	Dec.
					Earth	Sun	Heliocentric	Ecliptic		
Sun	1	-26.8	32.3'	—	0.99	—	—	218°31.0'	14h 25.3m	-14°24.3'
	15	-26.8	32.4'	—	0.99	—	—	232°34.4'	15h 21.4m	-18°27.9'
	30	-26.8	32.5'	—	0.99	—	—	247°43.7'	16h 24.6m	-21°37.9'
Mercury ♿	1	-0.2	5.8"	76%	1.15	0.44	298°33.2'	240°35.4'	15h 51.4m	-22°43.6'
	15	0.0	7.6"	45%	0.88	0.37	350°34.0'	252°47.6'	16h 50.4m	-24°57.7'
	30	4.6	9.8"	1%	0.68	0.31	73°29.2'	248°00.2'	16h 14.7m	-19°51.6'
Venus ♀	1	-3.9	10.6"	95%	1.58	0.72	172°04.6'	199°25.6'	13h 14.0m	-6°10.3'
	15	-3.9	10.3"	96%	1.62	0.72	194°43.7'	216°56.4'	14h 20.1m	-12°34.1'
	30	-3.9	10.1"	98%	1.66	0.72	218°51.0'	235°45.7'	15h 34.6m	-18°19.0'
Mars ♂	10	1.8	4.1"	96%	2.31	1.66	166°17.0'	188°34.7'	12h 33.4m	-2°18.3'
	20	1.7	4.2"	96%	2.24	1.66	170°40.3'	194°49.3'	12h 56.4m	-4°45.3'
Jupiter ♃	15	-2.3	38.1"	99%	5.17	5.05	321°00.8'	310°13.1'	20h 51.5m	-18°29.7'
Saturn ♄	15	0.5	15.1"	100%	10.94	9.96	240°28.5'	239°57.7'	15h 52.6m	-18°22.5'
Uranus ♅	15	5.7	3.5"	100%	20.01	19.11	257°54.4'	256°57.5'	17h 03.3m	-22°50.8'
Neptune ♆	15	8.0	2.2"	100%	31.01	30.25	273°06.0'	271°35.7'	18h 09.1m	-22°21.0'
Pluto ♇	15	13.8	0.1"	100%	30.65	29.74	214°49.1'	214°47.8'	14h 34.4m	1°50.2'

Inner Solar System



Moon Data

Last Quarter.....November 5 at 20h07m
 New Moon.....November 12 at 14h20m
 First Quarter.....November 19 at 9h04m
 Full Moon.....November 27 at 12h42m
 Last Quarter.....December 5 at 9h01m
 New Moon.....December 12 at 0h54m
 Perigee: Nov. 12 at 12h32m...356,871 km.
 Apogee: Nov. 25 at 22h03m...406,227 km.





The total lunar eclipse last May 4th wasn't visible from the Americas. George D. Georgiadis of Athens, Greece, went to Madagascar, where he photographed the Moon emerging from the Earth's shadow. When this photo was taken (20h04m UT), the bright star Alpha (α) Librae was still occulted by the Moon. He used a 14-inch SCT, telecompressor, and a 30-second exposure at f/5.8 on 200 ASA film.

Mercury

Mercury continues and finishes its apparition in the evening sky begun last month, but will never become very visible. At a peak elevation early in November of about 3°, 45 minutes after sunset, Mercury is hardly worth the bother of looking for with your telescope.

Venus

Venus is becoming less interesting as it drops lower day by day in the morning sky. By the end of the month, the planet will be too low to be seen easily in twilight. You can still locate Venus, however: center your scope on it low in the murk and follow the planet upward as dawn lightens the sky.

On the morning of the 11th, the nearly New Moon will pass just south of Venus, occulting the planet as seen from South America, the south Atlantic Ocean, and Antarctica.

Moon

One day after overtaking Venus

Satellites of Jupiter

0h00m UT

1	EJIC	. • • .	16	GEJJC	-- • .
2	GEIJC	. •• • .	17	GJIEC	. • • -- .
3	GJIEC	. • • • •	18	GIJEC	. • • • .
4	GJCE	. • •	19	EJIC	. • • .
5	ECIJG	•• • •	20	EJICG	. • • •
6	CJIG	. • • • .	21	IJEG	. • • •
7	CIJEG	. • • • •	22	CEJIG	. • • •
8	CEJGI	. • • •	23	CEGIJ	. • • •
9	CGEIJ	. • • • •	24	CGJEI	. • • • •
10	CGJIE	. • • • •	25	CGIJE	. • • • •
11	CGIJE	. • • • •	26	CEJI	. • • •
12	ECJG	•• • •	27	CEJG	. • • •
13	JIGC	. • • •	28	CIJEG	. • • •
14	IJECG	. • • •	29	CJIG	. • • •
15	EJGIC	. • • •	30	EIGJC	. • • •

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)



Right: November's \$100 "Best Astrophoto" award goes to David Mansbridge of Telford, Shropshire, England, for his photo of Mare Nectaris. Mr. Mansbridge used an 8-inch SCT, eyepiece projection to f/58, and a half-second exposure on 2415 film. **Left:** Californian Val Akins caught Comet Giacobini-Zinner moving northeastward in Cassiopeia on July 22nd. He guided on the stars, so the comet appears as a short fuzzy streak (8-inch SCT, 40 minutes on 3M 1000 film, f/5.8).

(November 12), the Moon becomes New. At the same time, a total solar eclipse occurs, but unfortunately, it is visible only from Antarctic waters near 135° to 180° west longitude. Even the partial phases are visible only from the southern part of South America.

Mars

Rising about 4 hours ahead of the Sun, Mars is a relatively prominent object in the predawn sky. It is moving southeastward along the ecliptic toward a meeting with the bright star Spica in Virgo early in December.

Although Mars is well above the southeastern horizon as morning twilight brightens, it still doesn't look like much in a telescope. On the 15th, it is only 4" across — about the same angular size as a very small lunar crater. Yet during the winter and spring months, you'll see Mars brighten steadily and grow larger. At its upcoming best opposition to the Sun, on July 10th, it will appear 23.2" across.

Minor Planets

1 Ceres (magnitude 7.9) is moving eastward in Leo, just to the east of second-magnitude Gamma (γ) Leonis. Its positions:

1st: 10h 20m 26s, 18° 17.1'
10th: 10h 33m 04s, 17° 42.5'
20th: 10h 46m 06s, 17° 11.4'
30th: 10h 57m 53s, 16° 50.2'

Ceres rises around midnight local time on

the 15th.

2 Pallas (7.8) is moving almost directly south in western Canis Minor. Its positions:

1st: 6h 22m 47s, -24° 13.7'
10th: 6h 24m 31s, -26° 43.7'
20th: 6h 23m 33s, -29° 13.3'
30th: 6h 19m 35s, -31° 13.8'

Pallas rises about 11:30 p.m. local time on the 15th.

4 Vesta (7.9) is about to vanish into the evening twilight, heading eastward along the ecliptic close to Antares. Its positions:

1st: 16h 59m 21s, -21° 34.5'
10th: 17h 19m 13s, -22° 15.9'
20th: 17h 41m 44s, -22° 50.1'
30th: 18h 04m 36s, -23° 11.4'

Vesta sets around 5:30 p.m. local time on the 15th.

216 Kleopatra (10.4) is moving retrograde (westward) in Taurus, just to the west of the Hyades. Its positions:

1st: 4h 22m 33s, 14° 12.3'
10th: 4h 16m 59s, 12° 30.6'
20th: 4h 09m 17s, 10° 41.6'
30th: 4h 01m 12s, 9° 05.3'

Kleopatra rises about 6:30 p.m. local time on the 15th.

To locate a minor planet, plot its dated positions lightly in pencil on a good star atlas (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by

hand what you see. Check the field a night or two later — the faint "star" that has moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

As the sky darkens after sunset, -2 magnitude Jupiter lies about due south and 25° to 40° above the horizon, depending on your latitude. With good atmospheric seeing, a telescope at medium to high magnification (150x to 300x) will show several features on Jupiter's cloudy surface besides the dark belts and the oval Red Spot. Look for ragged edges on the belts and search for white spots in the lighter-colored zones. You may have to observe the planet for many evenings before things suddenly "click" and you find yourself discerning far more detail than you did to begin with.

Saturn

Saturn is in conjunction with the Sun on November 23rd; it is out of telescopic view all month.

Uranus

Uranus dips out of sight in the southwest this month. The planet sets about 2 hours after the Sun, but its southerly declination (-23°) places Uranus low in the horizon murk long before it actually vanishes. Uranus won't return to good viewing until late winter, when it rises several hours ahead of the Sun.

Neptune

Neptune is soon to follow Uranus into the evening twilight. But you can still locate it early in November amidst the star-clutter of the summer Milky Way — if you have a low horizon to the south-southwest.

Right after sunset, locate the Teapot of Sagittarius (you may need binoculars). Then look for M-8, the Lagoon Nebula, some 6° above the star at the tip of the spout (Gamma Sagittarii). Having found this field of view with your telescope, look for Neptune about 2° northeast of the Lagoon. It's the "star" with a 2" grey-green disk that moves its position slightly from night to night.

Find it? If not, don't worry — Neptune will be back in late winter, soon after Uranus.

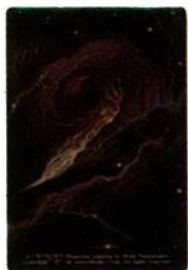
Comet Halley

November and December finder maps for Comet Halley appear in the Gazer's Gazette article beginning on page 64 of this issue.



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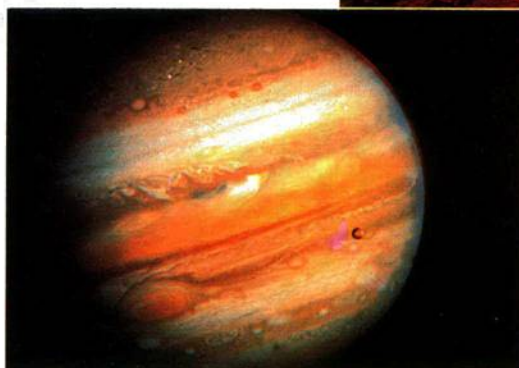
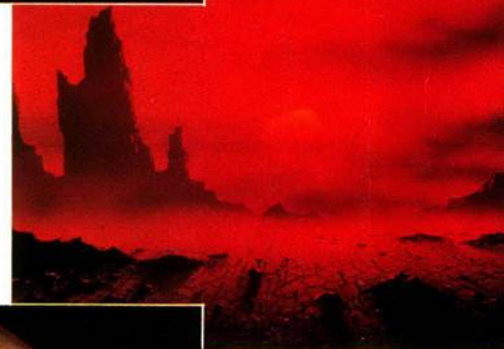
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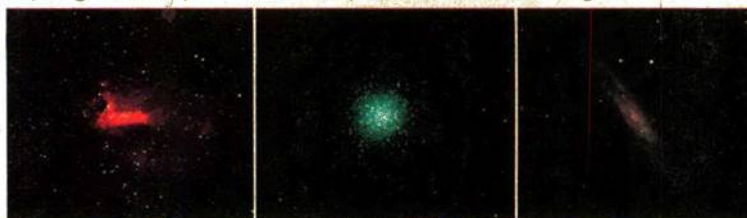
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